

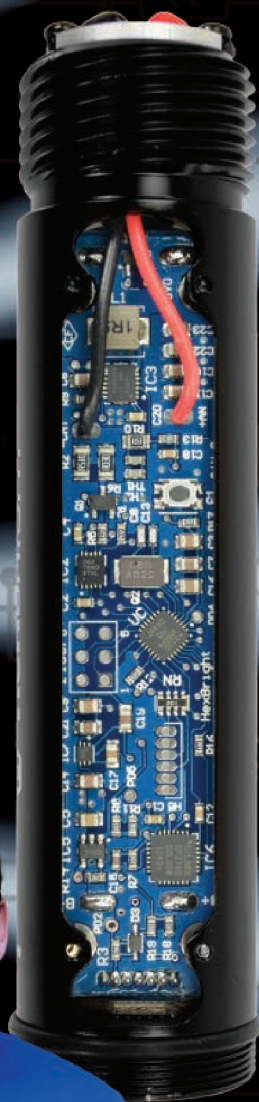
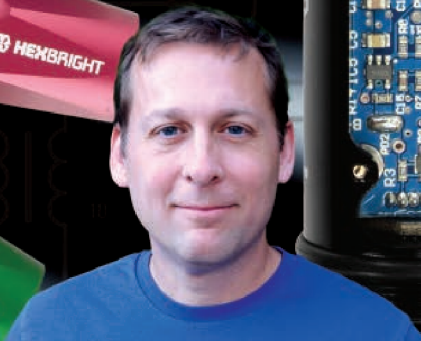
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December 2013

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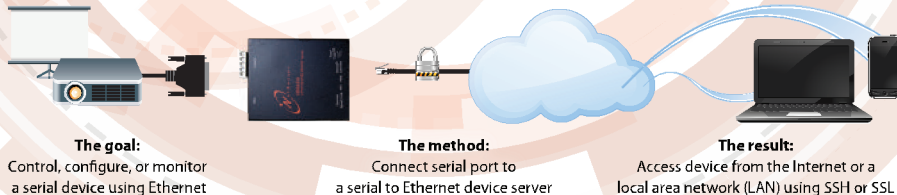
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# December 2013



## 28 Construction of a Low Budget 180 MHz RF Sweep Generator

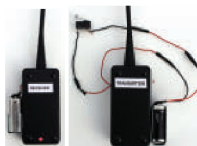
Sweep generators have a lot of uses in the design, prototyping, and troubleshooting of amps, filters, and other circuitry. I wanted one that could speed up these tasks by presenting several parameters at the same time. This is the unit I came up with.

■ By Robert Reed

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■ By Roger Secura



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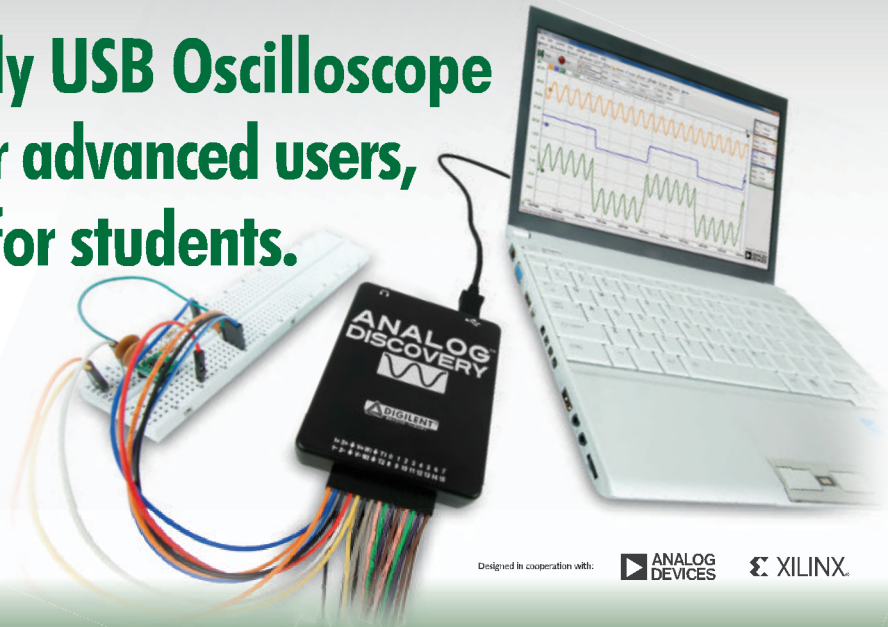
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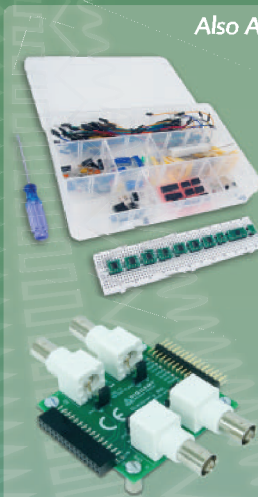
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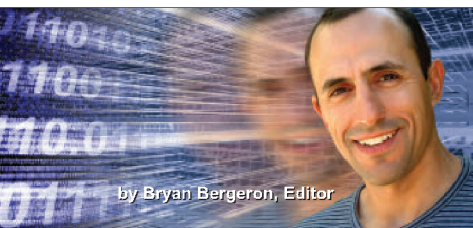
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by Bryan Bergeron, Editor

# DEVELOPING PERSPECTIVES

## Not Your Father's LEDs

**C**ontrolling the blink rate of an LED — the 'hello world' equivalent in hardware — is the most common way of demonstrating how to program a microcontroller. Many microcontrollers have a free onboard LED — pin 13 on the Arduino, for example — that makes the task even simpler. While such applications are useful, LED technology has come a long way since LEDs were first used as relatively low intensity monochromatic on-off indicators.

In addition to SMT LEDs the size of a grain of sand, there are jumbo LEDs, super-bright compact LEDs, monochromatic LEDs in a variety of colors, and multi-color LEDs that can reproduce any color. Then, there are the monochromatic and color LED matrices. Some have onboard microcontrollers that support high level graphic and text libraries, much like LCD displays. Then there are the powerful LED laser diodes — often referred to as simply laser diodes — that produce monochromatic coherent light.

Based on activity in online forums, LED matrices are clearly generating the most buzz. My current favorite is the 1.2" 8x8 bicolor matrix with I<sup>2</sup>C backpack — that is,

with onboard microcontroller — from Adafruit. At \$16, the red/green LED matrix isn't cheap, considering an Arduino or Raspberry Pi sells for about \$30. A less expensive option is a monochrome display (\$10) which I've used, as well. If money is no object, Adafruit has a 1024 LED 32x32 color matrix panel (\$120), but there's no onboard processor.

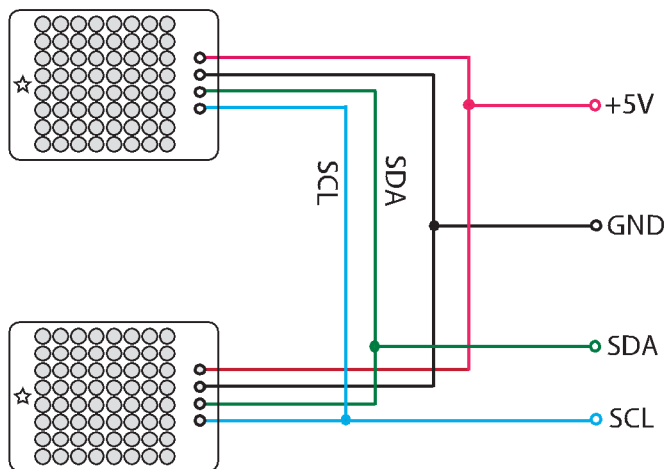
The smaller backpack-enabled LED matrices are a breeze to work with. There's no need to handle buffering, refresh rates, and relative PWM rates. As shown in the accompanying **figure**, all you need are power, ground, and two I<sup>2</sup>C leads from your microcontroller. The backpacks have address selection jumpers so that you can chain several matrices such as I did in the **graphic**. Most importantly, Adafruit offers an Arduino library that works across the monochrome and color 8x8 matrices.

Although I haven't used it, there's an impressive RGB 8x8 color LED matrix available from Parallax (\$40). Not surprisingly, its backpack is based on the powerful Propeller chip. Unlike the bicolor LED matrices from Adafruit, the more expensive Parallax display uses RGB LEDs; meaning it can display millions of different colors. Another big plus for the Parallax matrix is that only one

I/O pin is required. Parallax supports the matrix with libraries for the Arduino, BASIC Stamp, and Propeller chip.

If you want to experiment with a bare LED matrix and you have a microcontroller to dedicate to the project, the most economical option is probably an 8x8 red LED matrix from Seed Studio (\$2.25). Their large 2.5" bicolor 8x8 color LED matrix is also a good deal (\$5.50), but expect to spend a lot of time programming.

So, what's the value in an LED matrix? They make great alphanumeric displays, for one. I use them — together with proximity detection sensors — to simulate eye tracking in humanoid-looking robots. I'm sure you can think of additional uses — from a colorful time display, with, say, red digits for pm and green digits for am, to mood lighting. **NV**



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# READER FEEDBACK

## Getting (Tube) Testy

I've been looking at Bryan Bergeron's Developing Perspectives from last March and letters in Reader Feedback from Steve Borsher (June) and David Asselin (September) about tube matching. I've been in electronics since the tube days, when I built four different DIY tube amps. More recently, I've repaired or rebuilt several tube guitar amps — both vintage and newer — and I think I can provide a little information about tube matching.

First, regarding Mr. Asselin's question of how manufacturers match tubes for the sets they sell. According to the 2013 catalog of Parts Express ([www.parts-express.com](http://www.parts-express.com)), Sovtek and JJ tubes are tested for equal plate current on a "state-of-the-art computerized machine" after a 24 hour burn-in. Electro-Harmonix matches plate current after a 24 hour burn-in. Svetlana matches plate current and transconductance. Ruby Tubes are matched for plate current and transconductance, with the values marked on each tube.

According to *The Tube Amp Book*

(4.1 Edition, 2002) by Aspen Pittman (founder of Groove Tubes), they use actual amp circuits in a computerized test to match their tubes.

Regarding Mr. Borsher's Gold Lion tubes, Mr. Pittman says that Gold Lion was a line of premium tubes. Their KT88 was factory installed in the McIntosh 75, which many consider one of the best classic tube amps.

Most tube testers can be used for tube matching. There were two types of tube testers. The more expensive type — such as your Hickok — measured transconductance. At that time, I couldn't afford those so I used the cheaper type, called "emission" or "cathode emission" testers. These measured the cathode current of the tube. Since the cathode current is primarily plate current, this test would be similar to the plate current test used by several present-day tube manufacturers. Mr. Borsher's "good-bad" tester was probably this type.

Usually, they had a numeric scale in addition to the good-bad scale, or

Continued on page 73

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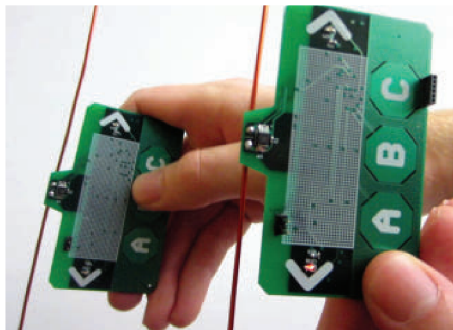
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## ADVANCED TECHNOLOGY



■ Ambient backscatter devices exchange data without the need for batteries.

### Look, Ma — No Batteries!

We live in a complex electromagnetic environment, filled with both low frequency fields (such as generated by electronic appliances and power lines) and radio frequency signals (as from cell phones, broadcast towers, and so on). Most of these things serve a specific purpose, but can also become sources of annoying electromagnetic interference. Is there some way that all the background noise can be harnessed for a practical purpose? University of Washington engineers have answered "yes" and demonstrated a new communication technique called "ambient backscatter" that uses existing TV and cellular transmissions to power battery-free devices. We're not talking about laptops or other equipment that requires a lot of power, but the concept could be highly applicable to RFID and Internet of Things types of apparatus.

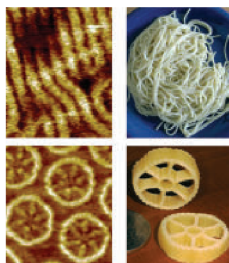
In operation, a backscatter device first picks up signals via an antenna and converts them to electricity in the range of tens to hundreds of microwatts. It then modifies, encodes, and reflects the signal to other devices which can respond to it in like fashion. In one demonstration, the researchers transferred funds from one payment card to another purely by leveraging the signals around them. The data capacity and working distance are pretty limited at present, as the devices can transfer only about 1 kb/s when 2.5 ft apart outside and 1.5 ft indoors. However, that is enough to send data such as sensor readings and text messages, and they can use transmissions from towers up to 6.5 mi (10.5 km) away. According to lead researcher Shyam Gollakota, the technique is "hopefully going to have applications in a number of areas including wearable computing, smart homes, and self-sustaining sensor networks." ▲

### Light-Emitting Pasta

As you probably know, cell phone and LED-based TV displays can employ standard silicon LEDs or the newer organic LED (OLED) technology. The latter devices are referred to as "organic" not because they are made without pesticides but because they are based on a compound that contains carbon. These compounds are referred to as "pi-conjugated polymers" which are plastic-like organic semiconductors consisting of a chain of repeating molecular units. OLEDs have several disadvantages including high cost and limited lifespan. In addition, because the light generated inside an OLED tends to be polarized in one direction, up to 80 percent of the light is trapped inside the device. This wastes quite a bit of power, which is why your OLED smartphone battery goes dead so quickly.

Apparently, the problem results from the molecular structure of conjugated polymers, which resembles a plate of spaghetti. To beat the system, University of Utah ([www.utah.edu](http://www.utah.edu)) physicist John Lupton has come up with a new organic molecule that is shaped more like wagon-wheel pasta. Called a "pi-conjugated spoked-wheel macrocycle," it is said to work the opposite of polarized sunglasses which screen out reflected glare. Instead, the molecules emit light randomly in all directions. According to Lupton, "We made a molecule that is perfectly symmetrical, and that makes the light it generates perfectly random. It can generate light more efficiently because it is scrambling the polarization. That holds promise for future OLEDs that would use less electricity and thus increase battery life for phones and for OLED light bulbs that are more efficient and cheaper to operate."

Unfortunately, we're talking about a scientific concept here, and real devices based on rotelle-shaped molecules are "quite a way down the road." Such molecules can also "catch" other molecules, so they might be useful in biological sensors, solar cells, and switches, so research continues. ▲



■ Molecular structure of OLEDs on the left and their pasta analogs on the right.



## COMPUTERS and NETWORKING

### New HP Chromebook

The latest in the Google-inspired notebook lineup is the Chromebook 11 from Hewlett Packard ([www.hp.com](http://www.hp.com)) which offers an 11.6 inch display, a fairly sleek and lightweight (2.3 lb) design, and an attractive price of \$279. Chromebooks — which are also produced in various flavors by Samsung, Lenovo, and Acer — have not exactly taken the market by storm, accounting for only about five percent of existing units. However, recent reports have it that the machines now account for up to 25 percent of all US notebook sales, so it appears that market acceptance is growing.

The new HP unit runs the same dual-core ARM-based Exynos 5250 processor that Samsung uses in its slightly cheaper version, and it comes with only 2 GB of RAM and a piddling 16 GB of internal storage. (The Chromebook concept is based largely on using cloud-based GoogleDrive storage instead, and you get 100 GB free for two years. After that, you're looking at \$4.99/month/100 GB.) For I/O, the device provides two USB ports, a headphone jack, and a charging port. The latter is a MicroUSB type, so you can charge it with the same charger you use for phones and tablets. Reviewers have generally praised the C11 for its solid keyboard and surprisingly decent sound (which comes from speakers

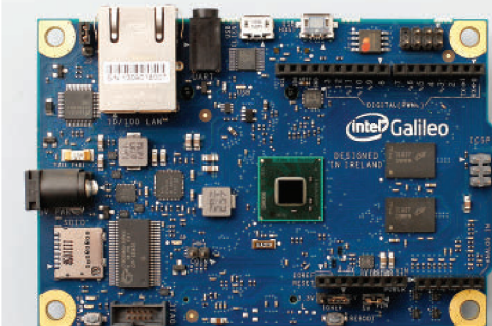


■ HP's Chromebook 11 — basic but cheap.

located under the keyboard). Because the operating system is based on Google's Chrome browser, you have to run stripped down adaptations of the apps that are available for Macs and Window-based computers. This isn't a powerhouse by any means, but if you spend most of your time surfing the web and listening to music, it might be a decent choice. ▲

### Intel + Arduino = Galileo

Perhaps drooling to take a bite out of the Raspberry Pi market, Intel ([www.intel.com](http://www.intel.com)) has announced a collaboration with Arduino ([www.arduino.cc](http://www.arduino.cc)) — an open



■ The Intel/Arduino Galileo single-board computer.

source hardware and software vendor that focuses on the build-it-yourself and educational communities. The company took the opportunity to unveil the Galileo development board, which is the first in a planned lineup of Arduino-compatible boards based on Intel technology. (Previous Arduino products employed Atmel microcontrollers.)

The Intel unit runs an open source Linux OS with the Arduino software libraries, enabling scalability and reuse of existing software called "sketches." It can be programmed through Mac OS, Windows, and Linux host operating software. The board is also designed to be hardware and software compatible with the Arduino shield ecosystem.

Galileo runs the Intel® Quark SoC X1000 — part of Intel's family of low power, small-core products. The X1000 is a 32-bit, single core, single-thread, Pentium® ISA-compatible CPU, operating at speeds up to 400 MHz. To get things rolling, Intel is donating 50,000 Galileo boards to 1,000 universities over the next year or so. If you're not lucky enough to get one of the freebies, you'll have to shell out about \$60 for one. ▲

## COMPUTERS and NETWORKING Continued

### Be a Digital Gourmet

If you like to tune in on the Food Network, it's likely that you wish you — like Guy Fieri — could get paid to drive around the country in a '67 Camaro and pig out on the tastiest food available. Well, sport, that isn't going to happen, but you can at least engage in the "pig out" part right from your own home, thanks to Goldbely ([www.goldbely.com](http://www.goldbely.com)). According to the website, "Our vision is an online marketplace that connects curious eaters with America's best gourmet food purveyors. We are creating an alternative to the food conglomerates and big box retailers that control most of the food world today."

So let's say you have heard amazing things about Katz's Delicatessen, the famous NYC castle of corned beef that has graced the Lower East Side since 1888. You no longer have to drive there to sample the famous brisket that is pickled for a full month, dry cured, and cooked to perfection. All you have to do is order the dinner for two from Goldbely, and you will soon receive your choice of one pound of pastrami or corned beef, two pickles (full or half sour), eight slices of rye bread, two knishes, half a pound of deli mustard, and your choice of a Katz's hat, T-shirt, or apron. The price is a mere \$60, including standard shipping.

Not into deli sandwiches? Well, how about one of Lou Malnati's Chicago deep dish pizzas or some ribs from Jack Stack's Barbecue in Kansas City? Or wings from the Anchor Bar in Buffalo? Or maybe even a pecan pie from Oklahoma City's Pioneer Pies? Even if you're not hungry now, a visit to the website is likely to change that. ▲



■ Corned beef sandwich from Katz's Deli, now available online.

## CIRCUITS and DEVICES



■ Murata's DMR20-10-DCM — a self-powered, panel-mounted nanometer.

### DC Meter Suitable for Battery Monitoring

If whatever it is you're building requires battery monitoring, you might be interested in the new DMR20-10-DCM "nanoMeter" — a self-powered, autoranging DC voltmeter from Murata Power Solutions ([www.murata-ps.com](http://www.murata-ps.com)). The panel-mounted meter fits an industry-standard "oil tight" 1.2 in (30.5 mm) round panel cutout and features an 0.3 in (7.6 mm) four-digit LED display. No additional components or power supply are needed; you just connect it to any 6 to 75 VDC supply. A jumper provides the ability to fix the resolution of 0.1V in the 6V to 75V input range, or 0.01V for inputs below 51V. The meter consumes less than 7 mA, making it useful in a range of battery-powered applications or for battery chargers, solar panels, and so on. The operating range is -25°C to 60°C. A single unit will set you back about \$45, but it drops to less than \$30 in high volumes. ▲

## Dump the Ugly Boxes

Once upon a time, your electronic creations — no matter how functionally amazing — necessarily looked amateurish because you had no choice but to house them in a crappy-looking generic box from RadioShack or some other dealer. Now, you're in luck! The wonders of digital printing have changed all that, and you can now get full color custom printing on your enclosures — whether you need one or 1,000 of them.

Polycase® has expanded their value-added services to include high-res, photo quality images printed directly on the boxes, eliminating the need for applying adhesive labels or other graphics. Plus, the images are UV cured, making them suitable for both indoor and outdoor use.

If you want to check the cost, all you have to do is log onto [www.polycase.com/quote](http://www.polycase.com/quote) and complete a series of steps (selecting the enclosure type, shape, surfaces, and so on), and you can get an instant price quote. The result will be a snazzy looking enclosure that looks like the product of a professional design studio. ▲

■ Custom-printed enclosure from Polycase.



■ Layout of the Flylink HD night vision recording watch.

## Christmas is Coming ...

It may fall into the category of useless junk that doesn't really work, but you have to be curious about the HD 1080P night vision recording waterproof watch from a Chinese outfit called Flylink Tech Co., Ltd. ([www.flylinktech.com](http://www.flylinktech.com)). According to the specs, the digital recording function offers 1920 x 1080p resolution at 30 frames/sec (even in complete darkness), 16-bit mono sound via the built-in mic, and operation up to 1.5 hr on a charge (rechargeable by USB or charger). Plus, it's waterproof down to 3 ATM. The device could come in handy if you want to videotape squids at night or expect to be knocked around by the police. Even if it doesn't work all that well, you can just give it away as a Christmas gift, and it won't matter (to you). The watch is currently available from the usual Internet stores for less than \$60. ▲

## INDUSTRY and the PROFESSION

### 2014 Communications and Networking Conference

The IEEE Communications Society ([www.comsoc.org](http://www.comsoc.org)) will be holding its 11th Consumer Communications and Networking Conference January 10-13. The annual conference is organized "with the objective of bringing together researchers, developers, and practitioners from academia and industry working in all areas of consumer communications and networking." The event will be held at Planet Hollywood, Las Vegas, which features such amenities as pleasure pools, the Playing Field sports lounge, the decadent Heart Bar (with "blackjack, cocktails, and a distinctly sensual atmosphere"), two spas, rows of shops, and even a chapel where you can marry that special someone you meet while in a drunken stupor. Oh, and the IEEE will be presenting some workshops, tutorials, and technical sessions, if you're into that sort of thing. Details at [ccnc2014.ieee-ccnc.org](http://ccnc2014.ieee-ccnc.org). **NV**



# The Ins and Outs of Python Programming

**In this month's Primer, we're going to continue our Python GPIO (general-purpose input/output) programming experiments with the Raspberry Pi. First, we'll carry out some basic Python experiments that use digital inputs on the Pi. Then, we will implement a Cylon Eye project using a 10-bar LED display. In the process, we'll learn something about a powerful Python programming technique called slicing. By the end of this article, we will have covered the basics of GPIO programming on the Pi, and will be ready to move on toward implementing our goal of interfacing PICAXE processors with the Raspberry Pi.**

## Experimenting With Digital Inputs on the Pi

Fortunately for us, implementing digital inputs on the Pi is very similar to doing the same thing on PICAXE processors. The main difference is that PICAXE processors only include internal pull-up resistors (which we can enable if we need them), while the Pi's internal resistors can be configured (on a pin by pin basis) as either pull-ups or pull-downs (or, of course, disabled entirely).

Figure 1 presents the four basic versions of Python's `GPIO.setup` command which we can use to configure a digital input pin on the Pi. As you can see, the syntax for

doing so is relatively straightforward. (Don't forget, capitalization matters!) However, there is one caveat that's very important to keep in mind: GPIO pins 2 and 3 — which can also be used for I<sup>2</sup>C communications — have external 1.8K I<sup>2</sup>C pull-up resistors soldered in place on the Pi's PCB (printed circuit board), so each of those two pins requires special consideration when used as a digital input pin. We'll get into the details shortly, but for now, let's begin with one of the other 15 GPIO pins.

## Experiment 1: Using an Internal Pull-up Resistor

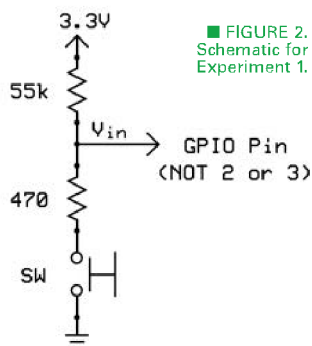
For our first GPIO input experiment, we're going to connect a momentary switch between ground and the GPIO 7 pin on our stripboard interface circuit, and a single LED between the GPIO 8 pin and ground. The simple schematic for this experiment is shown in Figure 2.

The Raspberry Pi documentation at [elinux.org](http://elinux.org) specifies the value of the internal pull-up resistors as being between 50K and 65K, and the value of the pull-down resistors as being between 50K and 60K. I decided to use 55K as a reasonable approximation for the internal resistors, which explains the value you see in Figure 2.

A close-up photo of my

breadboard circuit is shown in Figure 3. (The two-trace piece of stripboard near the right side of the photo is slightly longer because there are jumper wires underneath it that connect to the top power rails.) Note that I haven't included a current-limiting resistor for the LED or for the switch. We don't need any resistors on the breadboard because we already have a 470Ω resistor installed on each GPIO line on the Pi interface stripboard. (However, a resistorized LED will also work correctly in this experiment.)

Before we discuss the software for our first experiment, I need to mention that I still haven't found a way to open the N&V zipped program files on my Pi, so I have again included all the unzipped



Command	Pin Configuration
<code>GPIO.setup(pin, GPIO.IN)</code>	Input with no internal resistor
<code>GPIO.setup(pin, GPIO.IN, GPIO.PUD_UP)</code>	Input with internal pull-up resistor
<code>GPIO.setup(pin, GPIO.IN, GPIO.PUD_DOWN)</code>	Input with internal pull-down resistor
<code>GPIO.setup(pin, GPIO.IN, GPIO.PUD_OFF)</code>	Disable a previously enabled resistor

■ FIGURE 1. Python's `GPIO.setup` command options.

program files for this month's Primer on my website ([www.JRHackett.net/python.shtml](http://www.JRHackett.net/python.shtml)).

Before you read any further, you may want to download them to your Pi. Don't forget — you can't directly navigate to my Python page; just type the above address into your browser's URL bar.

Now, let's turn our attention to the main code that we will use for this experiment. We want the LED to immediately respond to a button press, and we want it to do so until we're convinced the program is working correctly. In Python, an "infinite while loop" is usually used in a situation like this (i.e., when we want a program to run indefinitely).

As you may remember from last time, a *while* loop continues to execute as long as the specified condition is true. As an example, consider the following code:

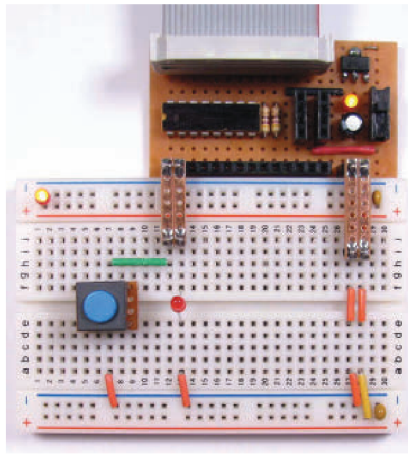
```
while 1 > 0:
    print("Hi Pi!")
```

Since 1 is always greater than 0, the *while* condition is always true, and this loop will continue to print "Hi Pi!" forever — or at least until we pull the plug or press *ctrl/c* on the keyboard (which is one way of terminating a running Python program).

There are many other *while* conditions we can use to accomplish the same thing. In Python, the word *False* is pre-defined as false, and *True* is pre-defined as true. (The capitalization counts; "false" and "true" are not predefined as anything.) Also, the number 0 is defined as False, and all other numbers (positive and negative) are defined as True. As a result, the most common way to write an infinite *while* loop is:

```
while 1:
    print("Hi Pi!")
```

Of course, we could accomplish the same thing by writing *while True*:



■ FIGURE 3. Breadboard Setup for Experiment 1.

or *while 1 == 1*: — or even *while 3.1416*:. The version you will see most often in books or on the Web is *while 1*; so we will also use that version of the infinite *while* loop.

When you've downloaded the *switchPUD\_UP.py* program to your Pi and opened it in IDLE, take a little time to read through the program listing. After you have done that, we can take a brief look at the main loop in the code:

```
while 1:
    if GPIO.input(switch) == 0:
        GPIO.output(LED, GPIO.HIGH)
    else:
        GPIO.output(LED, GPIO.LOW)
```

Because we're using the internal pull-up resistor, whenever the switch is **not** being pressed, the GPIO 7 pin is in a high state which means the value of the input is 1. When the switch is pressed, the 470Ω resistor on our stripboard circuit pulls the pin down to a low state, which has a value of 0. There's no time delay in the loop, so it iterates very rapidly.

The result is that the LED is on whenever the switch is being pressed (because the input equals 0), and off whenever the switch is not being pressed (because the input equals 1).

Functionally, the above loop is

identical to how we would accomplish the same task in PICAXE BASIC:

```
do
    if switch = 0 then
        high LED
    else
        low LED
    endif
loop
```

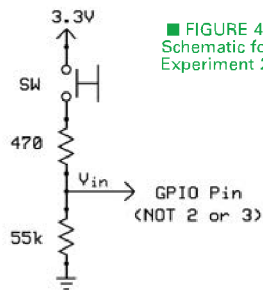
However, old habits are hard to break. Unlike PICAXE BASIC, Python uses a "==" symbol for "equals" and a "=" symbol for an assignment statement (e.g., LED = 8). Fortunately, each time we use the wrong symbol, IDLE points out the exact location of our mistake, so it's easy to spot.

That's all there is to *switchPUD\_UP.py* — run it on your Pi to see how it works.

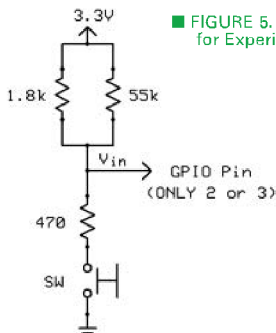
## Experiment 2: Using an Internal Pull-down Resistor

The internal pull-up resistors on PICAXE processors are certainly convenient, but they have always seemed "backwards" to me; pressing a button produces a value of 0, and releasing it produces a value of 1. (What's up with that?) Consequently, I was pleased to learn that the Pi also includes internal pull-down resistors because I think they result in more logically consistent programs. In order to see what I mean, let's reconfigure our circuit to implement an input that uses an internal pull-down resistor.

Figure 4 presents the reconfigured schematic for our pull-down circuit. As you can see, the pin is now pulled to ground by the internal 55k resistor; pressing the switch pulls it up toward +3.3V. The only difference in the breadboard circuit for a pulled-down switch is that the connection between the switch and the power rail is now made to +3.3V rather than ground. There's no need to show another photo of the breadboard setup; just change the switch's connection

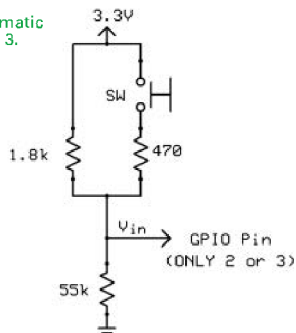


■ FIGURE 4. Schematic for Experiment 2.



■ FIGURE 5. Schematic for Experiment 3.

Internal 55k Pullup



Internal 55k Pulldown

from ground to +3.3V.

The software is also easy to modify. Only two changes are needed: Replace the `GPIO.setup` command with the correct syntax for a pull-down resistor, and replace the 0 in the `if` statement with a 1:

```
while 1:
    if GPIO.input(switch) == 1:
        GPIO.output(LED, GPIO.HIGH)
    else:
        GPIO.output(LED, GPIO.LOW)
```

To me, this makes more sense; if the input is raised to high (i.e., the switch is pressed), the output becomes high (i.e., the LED is lit).

So, modify your breadboard circuit, download the `switchPUD_DOWN.py` program to your Pi, and run it. The program functions identically to the earlier `switchPUD_UP.py` program, but I'll sleep a little better because the program is more logically consistent.

## Experiment 3: What about the GPIO 2 and 3 pins?

As I mentioned earlier, GPIO pins 2 and 3 function somewhat differently when used as input pins due to the external 1.8k pullup resistors that are soldered in place on the Pi's PCB. As a result, if you enable either an internal pull-up or pull-down resistor, you end up with three resistors in the circuit, with two of them in parallel (see Figure 5). I used the GPIO 2 pin to test both circuits (but the GPIO 3 pin functions

identically) and here's what I found:

The pull-up version (left side of Figure 5) works, but it also works without enabling the pull-up resistor, so there's no need to use the internal pull-up.

The pull-down version (right side of Figure 5) doesn't work at all. Whether the switch is pressed or not, the external 1.8k resistor pulls the voltage high enough so that the input is always in a high state.

If you want to experiment with either of the circuits in Figure 5, don't forget that a 470Ω resistor needs to be installed in the four-pin female header that's in line with the pin that you choose (GPIO 2 or 3). If you leave that resistor out, there will be no electrical connection between the GPIO pin and your breadboard, so switch presses will have absolutely no effect on the input pin.

Of course, you're free to draw your own conclusions, but here's what I've decided after experimenting with the Pi's input pins:

1. Pull-down resistors are preferable because their use results in more logical programming. Therefore, I'll avoid using GPIO pins 2 and 3 for digital inputs whenever I can.
2. If I've already used every other GPIO pin and still need an input, I'll use the GPIO 2 or 3 pin without enabling either internal resistor. In

other words, I'll use the onboard 1.8k 1°C resistor as a pull-up. If you want to experiment with this option, Figure 6 shows a photo of the breadboard circuit I used for a switch on the GPIO 2 pin, and a suitable Python program (`switchGPIO2.py`) is included in this month's downloads. Again, don't forget to insert a 470Ω resistor in the four-pin female header as shown in the photo.

Now that we have a basic understanding of how to use the internal pull-up/pull-down resistors on the Pi's GPIO pins, we can move on to implementing our Cylon Eye project.

## What's a Cylon Eye, anyway?

If you're a science fiction fan (and old enough!), you probably already know the answer to that question; if not, here's a brief explanation: The Cylon Eye was first seen in the 1978 television series *Battlestar Galactica*. This science fiction show included a race of robots called *Cylons* who had a single, sinister red "eye" that repetitively scanned the environment. The original show only lasted one season, but ever since the majority of introductions to microcontroller programming have included some form of an LED-based Cylon Eye project — probably because it's so



much fun to watch the LEDs scan back and forth from side to side. (The Syfy channel featured a remake of the original series.)

In order to implement a Cylon Eye, all we need to do is line up several LEDs in a straight row with each one connected to its own output pin, and write the necessary software to produce a fairly rapid back and forth scanning effect. Of course, we could use a bunch of discrete LEDs for this purpose, but an LED bar display produces a much nicer effect, so that's what we'll use. (If you prefer the discrete LED approach, that's fine too.)

Since our stripboard interface circuit for the Pi has 10 of its 12 GPIO pins in a nice contiguous row, it's a perfect match for a 10-bar LED display which is the most commonly available size. If you don't already have one on hand, check out the one that's available on my website ([www.JRHackett.net/LEDs.shtml](http://www.JRHackett.net/LEDs.shtml)).

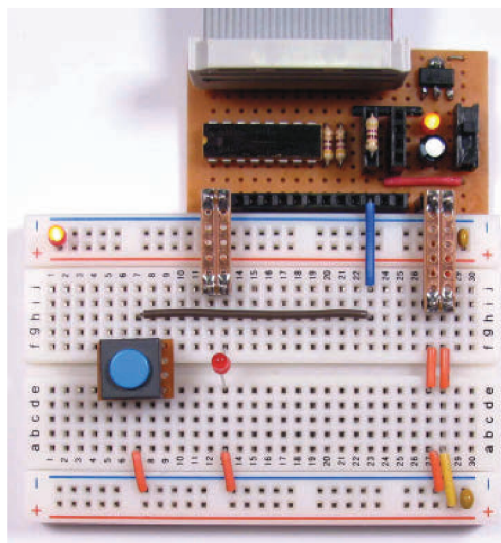
**Figure 7** is a photo of my hardware setup for our Cylon Eye experiment. In the **photo**, the LED bar display is directly in line with the first 10 GPIO pins (7, 8, ... 15, 14) on the Pi interface board. The display's pins span the center portion of the breadboard, and they are long enough to be firmly inserted into it. Also, the display is oriented so that its 10 cathode pins are running along its lower edge.

On many bar displays, the cathode side isn't marked on the display itself; you need to refer to the datasheet to figure that out. However, there's no harm in initially inserting the display backwards — the LEDs just won't light. If that happens to you, just rotate the display 180° and try it again. Once you have determined the cathode side of the display, you may want to mark that side with a black dot.

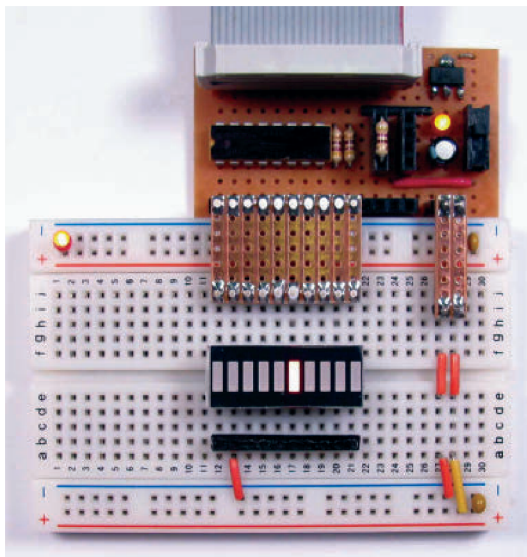
As I'm sure you know by now, I like to keep my breadboard wiring as neat as possible, so I've included two simple stripboard circuits in this setup. Just above the LED display, you can see an inverted piece of stripboard containing 10 traces with seven holes each. (A 10-pin male header is soldered at the top and bottom ends of each trace.) Of course, you can also just use 10 jumper wires to connect the GPIO pins to the anode of each LED, but the stripboard connector is quick and easy to make, and it comes in handy for a variety of purposes.

The second piece of stripboard is even simpler, but it isn't as easy to spot — it's the long black rectangle just below the LED bar display. It consists of a single stripboard trace with 10 holes. I inverted the trace, placed it on top of a 10-pin male header, and soldered each pin of the header to the stripboard. Of course, I couldn't stop there! I also sanded off the short ends of the header pins and painted the whole thing black. (Sometimes, I just can't help myself!)

This second piece of stripboard eliminates the necessity of using another 10 jumper wires to connect



■ **FIGURE 6.** Breadboard Setup for Experiment 3.



■ **FIGURE 7.** Breadboard Setup for Cylon Eye Project.

the 10 LED cathodes to ground; connecting any one of the 10 positions to ground automatically grounds all 10 LED cathodes.

In **Figure 7**, you can also see that I haven't included any current-limiting resistors; they aren't necessary because we already have the 470Ω resistors installed on each GPIO line on the Pi interface stripboard. (I did forget to remove the 470Ω resistor from the GPIO 2 pin that we used in our previous experiment, but it doesn't matter.)

## Developing a Python Cylon Eye Program

Now that we've completed our hardware setup, we're ready to "focus" on the software that's needed to produce the scanning Cylon Eye effect. In order to get the job done, we need to first discuss a couple of Python's list processing features that are new to us.

In the previous installment of the Primer, I mentioned that Python lists are *iterable* which means that the items in a list can be used to control the number of times that a loop repeats, or iterates. A simple example should clarify what this means. For our Cylon Eye experiment, our LEDs are connected to 10 GPIO lines which we need to configure as outputs. Of course, we could just write 10 statements to accomplish this:

```
GPIO.setup(7,GPIO.OUT)
GPIO.setup(8,GPIO.OUT)
GPIO.setup(9,GPIO.OUT)
# etc.
```

However, Python provides an easier and more powerful solution. We can declare our 10 outputs as a list, and then use a simple loop to configure all 10 pins. As we saw last time, a Python list is always enclosed in brackets, so we can declare our LED list as follows:

```
LEDs=[7,8,9,10,11,23,22,16,15,14]
```

Once we have done that, we can simply write:

```
for LED in LEDs:
    GPIO.setup(LED,GPIO.OUT)
```

This loop executes 10 times, advancing through each item in the LEDs list. In the first iteration, pin 7 is configured as an output; in the second iteration, pin 8 is configured as an output; and so on, until all 10 pins have been properly configured.

Another new Python feature that we'll be using is a *user-defined function* which is similar to a subroutine in PICAXE BASIC. For example, if we wanted to write a subroutine to blink an LED in BASIC, we could do it as follows (assuming the LED variable has already been defined):

```
blink:
    high LED
    pause 100
    low LED
    return
```

In Python, we can accomplish the same thing (without having to define LED earlier in the program) by writing:

```
def blink(LED):
    GPIO.output(LED,GPIO.HIGH)
    sleep(.1)
    GPIO.output(LED,GPIO.LOW)
```

Before going any further, I want to mention a few important details of writing user-defined functions:

- The keyword *def* (short for define) is necessary; it cannot be omitted.
- In PICAXE BASIC, we usually place our subroutines below the main portion of the code (but they can just as easily be placed above the main code). In Python, user-defined functions must be declared *before* the main code or a syntax error will result.
- In PICAXE BASIC, in order to "jump to" a subroutine, we need to include the word *gosub* (or *call*). For example, we need to write *gosub blink* (or *call blink*); in Python, no additional keyword is used. For

example, in the main portion of a Python program to blink each LED in order, we can just write:

```
for LED in LEDs:
    blink(LED)
```

The term inside the parentheses is called an argument or a parameter, and it's passed to the user-defined function. It may seem a little strange, but the name of the parameter does not need to match the name that is used in the function. In other words, in the main portion of the code, the following would also work:

```
for redthing in LEDs:
    blink(redthing)
```

In this case, the loop iterates through our LEDs list, sequentially assigning each item in the list to the *redthing* variable which is then passed to the LED variable in our user-defined function. Of course, in this case, it would be very confusing to use two different variables, but there are times when you want a general-purpose function that can be used to process more than one variable.

It's also possible to write a user-defined function that doesn't require any parameters, but unlike some other programming languages Python still requires the empty parentheses to be included. For example:

```
def myfunction():
    # statements here
```

Finally, note that there is no need for anything like the *return* statement in a BASIC subroutine. As we have already seen, Python's indentation structure automatically takes care of that. When we finish typing in our *blink(LED)* user-defined function, the next line in our program will be out-dented, so Python "knows" where our function ends.

At that point in the program's execution, the program flow automatically returns to the next instruction in the main portion of the code.

Now, let's turn our attention to the main code that we need to implement our Cylon Eye project. We want our LED display to scan back and forth forever (or at least until we get tired of watching it), so we again need to use an infinite *while* loop.

Scanning through the LEDs in one direction is a simple matter:

```
while 1:
    for LED in LEDs:
        blink(LED)
```

However, the question remains, "How can we scan back in the other direction?" My first solution to this problem was to define two different lists:

```
LEDs_L2R=[7,8,3,10,11,23,22,15,15,14]
LEDs_R2L=[5,12,22,23,11,10,9,8]
```

The first list (*LEDs\_L2R*) is short for "LEDs Left to Right." As you can see, it's identical to our original *LEDs* list, so I used it in the same way to configure the 10 output pins. In the second list (*LEDs\_R2L*) which, of course, is short for "LEDs Right to Left," I omitted the first and last LEDs, reversed the order of the remaining eight LEDs, and used both loops in the main code as follows:

```
while 1:
    for LED in LEDs_L2R:
        blink(LED)
    for LED in LEDs_R2L:
        blink(LED)
```

This solution produced the exact scanning effect that I wanted, but I was sure that Python would offer a more elegant solution, so I did some online searching. What I found is a Python technique called "slicing," and it turns out to be so powerful and flexible that I'm sure we'll be using it in several of our future programs.

For our Cylon Eye project, we only need the simplest form of slicing, so that's all we'll discuss this time. If you're interested in the more powerful forms of slicing, just search for "python slice list" (without the quotes), and you'll find a wealth of information. (You'll also discover that

other Python data structures can be sliced.)

## There's More Than One Way to Slice a List

In order to facilitate our discussion of slicing, you may want to refer to **Table 1** which presents our original *LEDs* list, along with the zero-based index of each element in the list.

Elements	7	8	9	10	11	23	22	18	15	14
Indexes	0	1	2	3	4	5	6	7	8	9

Table 1.

Essentially, slicing a list returns a subset of the elements in the list. Python provides several different syntaxes for slicing a list, but we're only going to discuss two of the simplest versions:

```
myList[start:end]
myList[start:end:step]
```

As you've probably already guessed, the process of slicing a list is very similar to executing a PICAXE *for/next* loop. However, there is one important (and sometimes confusing) difference: In PICAXE BASIC, the statement *for myVar = 2 to 7* produces a loop that iterates through the values 2, 3, 4, 5, 6, and 7. In Python, the statement *LEDs[2:7]* returns a list that contains the elements of the *LEDs* list that have indexes of 2, 3, 4, 5, and 6 (but not 7). (Note: If the *step* parameter is omitted, it defaults to 1 in both languages.)

In other words, when slicing a list, the element at the *start* index is **included** in the returned list, but the element at the *end* index is **excluded**. This may seem confusing at first, but it also has an advantage in that you can easily subtract the *start* index from the *end* index to determine how many elements will be returned ( $7-2=5$ ). In a BASIC *for/next* loop, it's easy to mistakenly think that a *for myVar = 2 to 7* loop will execute five times when, in fact, it executes six times.

The best way to become familiar with the process of slicing a loop is to practice, and the easiest way to do that is in the IDLE interactive editor. For example, at the IDLE interactive prompt ("*>>>*"), just type the following:

```
_LEDs=[7,8,9,10,11,23,22,18,15,14]
```

When you press the Enter key nothing will seem to happen, but the list will have been defined in IDLE. Next, using the indexes and not the elements (and remembering that Python list indexes are zero based), type in a slice. Before you press Enter, predict what the slice will return, and see if you are correct.

When you feel comfortable with the process of slicing a list, we're ready to take a look at exactly how slicing can be used in our Cylon Eye program. In order to do that, we need to discuss the second slicing syntax that we saw earlier:

```
myList[start:end:step]
```

Similarly to the BASIC *for/next* loop, the optional *step* parameter can be used to modify the iteration process. For example, assuming that we have previously defined our *LEDs* list as *[7,8,9,10,11,23,22,18,15,14]*, correctly configured them as outputs, and included a *blink(LED)* user-defined function, consider the following Python code snippet:

```
for LED in LEDs[0:8:2]:
    blink(LED)
```

Which LEDs do you think will be blinked? If you answered "7, 9, 11, and 22," you win a smiley face. (If you also included LED 15, you forgot that the end index is *not* included in the slice.)

Now, try this one:

```
for LED in LEDs[0:]:
    blink(LED)
```

If your answer is "all of them, except LED 14," you win the prize! Here's another test:

```
for LED in LEDs[9:0:-1]:
    blink(LED)
```

If your answer is “all of them (from right to left), except LED 7,” congratulations — you passed the test! Now, for the final exam, let’s take our last two snippets, and put them together in an infinite while loop:

```
while 1:
    for LED in LEDs[0:9]:
        blink(LED)
    for LED in LEDs[9:0:-1]:
        blink(LED)
```

What happens this time? (Think about that a bit before you continue reading.)

LED 14 is skipped as the display scans from left to right, but it’s the first one to light as the display starts back from right to left. At the end of the right to left scan, LED 7 is skipped, and the first iteration of the while loop is completed. However, in the next iteration of the loop, LED 7 is the first one to light, and the whole sequence repeats itself forever (or until we press the ctrl-c key).

If you haven’t already done so, run the `cyon10.py` program on your Pi. When you’re sure it’s scanning correctly and you get tired of watching the LEDs scan back and

forth, pay attention to the display as you press ctrl-c to terminate the program. What happens and how do you explain that result?

Next, type `GPIO.cleanup()` at IDLE’s interactive prompt (“>>>”). What happens then and why? Finally, why didn’t we see something similar in our earlier experiments? (Questions, questions!)

## What’s next for the PICAXE Pythonistas?

That’s it for this month. Next time, we’ll address the above questions and then begin to experiment with interfacing PICAXE processors with the Pi. In the meantime, continue to practice slicing lists and learning as much as you can about Python.

And don’t forget to have fun!

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- Buzzer for simple sounds and music

In this column, Russ answers questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions. Send all questions and comments to: [Q&A@nutsvolts.com](mailto:Q&A@nutsvolts.com)

## • Bandpass Filter Calculations

## • 12 Volt Control

## • NiCad Battery Chargers

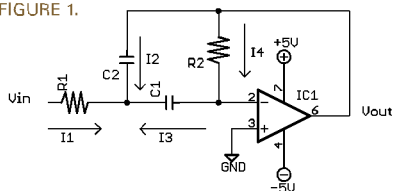
Post comments on this article and find any associated files and/or downloads at [www.nutsvolts.com/index.php?/magazine/article/december2013\\_QA](http://www.nutsvolts.com/index.php?/magazine/article/december2013_QA).

## Bandpass Filter Calculations

Here is a simple bandpass filter (see **Figure 1**). I would like to know how to calculate the values of R and C for a specific center frequency. Any help is greatly appreciated.

— Bob Wojcik

■ FIGURE 1.



I don't think I have the mathematical ability to do the calculation, but I can tell you how I would approach the problem. Using Kirchoff's law that the sum of currents at a point is zero, and defining the currents as in **Figure 1**, then:

$I_1 = (V_{in} - V_a)/R_1$ ,  $I_2 = (V_{out} - V_a)j\omega C_2$ ,  $I_3 = (V_a - V_b)j\omega C_1$   
 Since the op-amp input is virtual ground,  $V_b = 0$  and,  $I_3 = I_4$  therefore  $V_a = V_{out}/R_2 j\omega C_1$   
 At [hmc.edu](http://hmc.edu), I find that  $Z = e^s = e^{(\sigma + j\omega)}$

Taking the antilog of both sides:  $s = \sigma + j\omega$ . If the analysis is limited to sine waves,  $\sigma = 0$ .

Adding  $I_1 + I_2 + I_3$  and  $I_3 = I_4$  and solving for  $V_a$ :  
 $V_a = (sC_2V_{out} + V_{in}/R_1)/(R_1(1 + sR_1(C_2 + C_1))) = V_{out}/R_2 sC_1$

Eliminating  $V_a$  and solving for  $V_{out}/V_{in}$ :

$$V_{out}/V_{in} = -(s/R_1 C_2)/(s^2 + s(C_2 + C_1)/(R_2 C_1 C_2) + 1/(R_1 R_2 C_1 C_2)) \quad (1)$$

The equation for a bandpass filter is:

$$V_{out}/V_{in} = H(s) = s/(s^2 + s\omega_0/Q + \omega_0^2) \quad (2)$$

When  $s^2 = \omega_0^2$  those terms cancel and the gain is:  $Q/\omega_0$

$$\omega_0 = 2\pi F_0$$

$$Q = F_0/(F_2 - F_1)$$

$F_2$  = upper -3 dB frequency

$F_1$  = lower -3 dB frequency

$$F_0 = \text{center frequency} = (F_1 F_2)^{1/2}$$

Equating like terms of (1) and (2) and making  $C_1 = C_2 = C$ , I get the values of  $R_1$  and  $R_2$ :

$$R_1 = Q/\omega_0/C/\text{Gain}$$

$$R_2 = 2^4 Q/C/\omega_0$$

To test the results, I designed a filter with a gain of 100 (40 dB),  $F_1 = 7.0$  kHz,  $F_2 = 8.0$  kHz, and  $C = 1.0$  nF. The peak frequency should be  $(56)^{1/2} = 7.48$  kHz. The response is shown in **Figure 2**.

I spent an inordinate amount of time on this because it is very easy to make an error that carries through and then I end up with gibberish. However, what I lack in accuracy I make up for in persistence.

The response in **Figure 2** is not exact; the gain, peak

Can't figure out that pesky circuit or don't understand the components?

Let Russ help!

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frequency, and Q are all lower than calculated. I blame that on the op-amp limited bandwidth and phase shift. I did try a perfect gain stage (Figure 3) and although the gain is good, the peak frequency and Q are about 6% low. I don't know how to explain that.

## Programmable Lock

**Q** I think I have an interesting project. I bought a 3x4 matrix keypad and I thought I would make a programmable lock. It didn't take long to figure out this is not a simple thing to do. LSI/CSI LS7223 is an IC you can get but it's expensive. What do you think?

— Ken Brown

**A** This is outside my comfort zone. I have never done a keypad entry before. However, Bryan Bergeron in his October issue editorial says we should get out of our comfort zone and learn something new. I'll think about it.

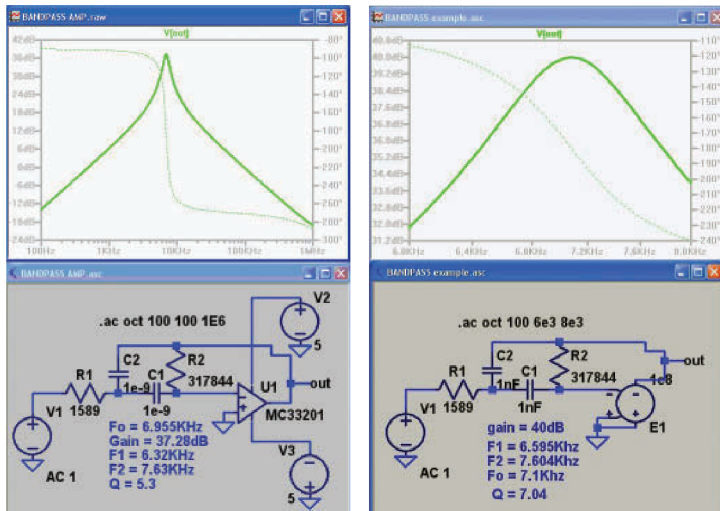
## MAILBAG

**Re: ESD Instrument Circuits, pages 16-18, September 2013:**

Your questions reminded me of an instrument I saw several years ago, so I don't recall all of the details but the principle of operation was pretty simple. It used a rotating grounded electrostatic shield with openings so that a fixed electrode behind the rotor is alternately exposed and shielded from the external static field being measured. The fixed electrode would be connected to the input of a very high impedance AC amplifier that's tuned to the field interruption rate. A synchronous demodulator would be ideal for extracting the final DC measurement value, and its carrier signal could come from a shield rotation sensor of some sort. Does that make sense?

Mike Hardwick

*Yes, I am sure that would work. Now, how would one do that solid-state? Kerr cell?*



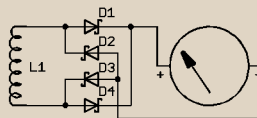
■ FIGURE 2.

■ FIGURE 3.

## 12 Volt Control

**Q** I want to upgrade my receiver to one that supports the latest surround formats, but modern receivers use 12 volt triggers instead of switched outlets. My old subwoofer is satisfactory for now, except for its auto-on feature that falls asleep and thumps back on.

Victor Davis wrote to tell about his reproduction of Michael Faraday's experiment which shows the principle of the dynamo. You need a sensitive micro ammeter or center zero galvanometer, a coil of many turns, and a strong magnet. If the meter only indicates positive current, you will need a bridge rectifier. Use germanium or Schottky diodes for best results. The procedure is simple: Insert the magnet in the coil; it will cause a current that is shown on the meter. When the magnet is removed, an opposite current is generated.



■ FIGURE A.

*Thanks, Victor; the schematic is in Figure A. (Victor sent several files on this topic that are posted at the article link.)*

Could one of those optically isolated triacs I've seen in previous projects do the job without another power supply? Is any other circuitry required beyond the series

resistor for the LED trigger? Commercial versions of this are expensive because they are packaged with cords, outlets, and overload protection, and have to be UL certified. Perhaps I could just hang the circuit inside across the sub's power switch where it can do no harm if it failed either open or shorted. My old sub is under the 250 watt limit of my old receiver's outlet, but can you recommend or tell me how to size components that can handle future higher powered subs? I probably could use a second small one for a turntable and outboard phono preamp; I can think of other uses in a home theater. One more question: Can triac power switching be used with subwoofer amps that use switching power supplies?

**A** I don't know about 12 volt trigger specifications, but solid-state relays require 5 mA to 10 mA current to operate, and any respectable output should handle that. In order to be useful, the 12 volt trigger must remain high as long as you want the relay to be ON. Electro-mechanical relays are expensive, bulky, and require a power supply, so I would not go that route. The LED in the solid-state relay drops about one to 1.5 volts, so a series resistor to limit the current is all that is needed. You will want a relay that switches at zero crossings in order to limit voltage spikes.

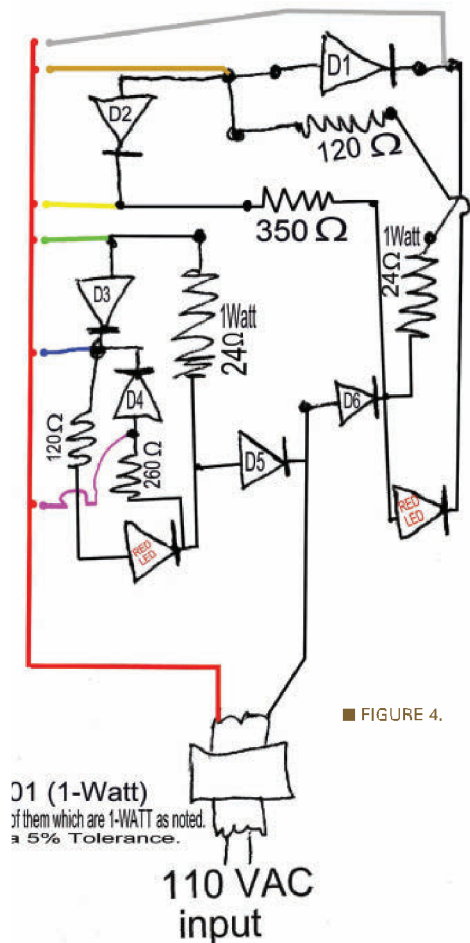
The IXYS CPC40055ST is such a relay that will handle 250 watts with no heatsink, or 1,000 watts with a heatsink and fan. I don't see a problem using any solid-state relay with switching power supplies.

## NiCad Battery Chargers

**Q** I have two (GE) nickel cadmium battery chargers (2.9/8.7 VDC at 105/12 mA) which generate a lot of noise (humming) when batteries are inserted for (re)charge (see **Figure 4**); therefore, no charge takes place. (Although I tried to the best of my abilities, I don't know if my schematic is that accurate.)

The rectifying diodes (1N4001) are rated at one watt/one amp; I think that they're at fault. Should I just replace the six rectifying diodes or upgrade all of them to 1N5400 (50 PIV at three amps)? None of the resistors are burnt and the two red LEDs do light up. What should I do?

**A** Since there are only resistors and diodes in the circuit, I agree that the diodes must be at fault: 50 volt diodes in a 110 VAC circuit could be overstressed, so I would replace all of them with 1N4004s. One amp should be adequate, and the higher voltage rating is not more expensive. I don't know what could be causing the humming, but hopefully that will stop when you get it working correctly. **NV**





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## ACTIVE IR TOGGLE / PROXIMITY SWITCH

**T**he J2 LED Lighting, LLC P/N AIR1 (Active Infra-Red) Proximity and Toggle switch provides on and off control of 12 or 24 volt DC LED lights by a non-contact means. The AIR1 uses an active infrared LED emitter and a corresponding photodetector to sense reflected IR energy. Typical target materials — such as a hand or painted surface — provide adequate IR energy reflections for the AIR1. The infrared emitter detector pair provides near field proximity sensing which occurs in a range of 1.2" to 3.9" typical. Sensing is provided in a 100 degree wide field of view. The unit discriminates against ambient visible light to reduce false triggering.

The AIR1 operates in either one of two modes which are selectable with a micro slide switch on the side of the unit's body. One mode is door proximity in which the AIR1 functions as a photoelectric sensor switch detecting the presence of an object such as a cabinet door. With the AIR1 mounted within the cabinet and the door in the closed position, the AIR1 senses IR reflection from the door and

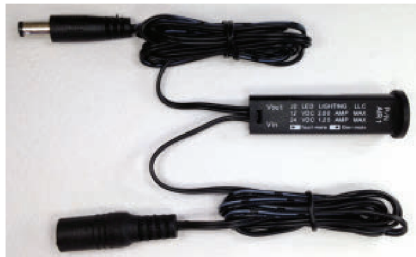
maintains the controlled LED light in the off state. In the absence of a reflection from the door in an open position, the unit turns on providing power to the LED light source.

The second mode is a noncontact "touchless" toggle switch. With a wave of an object (such as a hand) in front of the sensor, the AIR1 will toggle with each pass of an IR reflective object. This provides a means of "touchless" on/off control to the LED lighting device, eliminating the need for electro-mechanically switched power.

The AIR1 operates with 12 or 24 volt DC lighting systems, and can switch a maximum of two amps at 12 volts and 1.25 amps at 24 volts. The unit provides up to 24 watts of lighting control when using a 12 volt system or up to 30 watts on a 24 volt system.

The AIR1 is equipped with a barrel connector type DC power jack and plug. The connectors are of the 5.5 mm x 2.1 mm size with a positive center connection. The AIR1 is compatible with other J2 LED Lighting accessories of the same connector type.

The AIR1 control body has a removable ring bezel; the ring bezel is used for through panel applications. The ring bezel is swage fit and can be easily removed for utilizing flats of the unit's body with



double-sided tape for mounting.

Pricing is \$13.99 in single quantities, or quantities of 10 at \$12.24 each.

## MICRO EFFECTS DIMMER

**A**lso available from J2 LED Lighting is the MED1 Micro Effects Dimmer which provides dimming, multimode effects, and on/off control of 5–24 volt DC LED lights. The unit features a simple tactile three-button interface: mode, speed, and light. The variety of effects combined with the simplicity of use makes this a great control for low complexity projects.

The MED1 has eight dynamic effect modes and 10 speed levels. The light button is used to switch the unit to standard static dimming. In the static dimming mode, the speed button provides 10 brightness steps.

The speed button is also used to turn the unit off when it is held more than one second. Any button can be used to turn the unit back on.

Mode effects patterns include:


- 1) Up/Down varying brightness – always on
- 2) Strobe – fast
- 3) Blinking – long on
- 4) Blinking – long off
- 5) Flash – burst of pulses (emergency vehicle light)
- 6) Strobe – slow (beacon light)
- 7) Up/Down – flame flicker – always on
- 8) Up/Down – ramp up on, ramp down off – repeat

The MED1 operates with 5, 9, 12, or 24 volt DC lighting systems and can switch a maximum of four amps. The unit provides up to 20 watts of lighting control when using a five volt system; 48 watts on 12 volt; or up to 96 watts of lighting on a 24 volt system. The control may be




operated from a nine volt battery for portable applications. It's recommended to limit the LED light load current to 100 mA for battery life.

The MED1 is equipped with a barrel connector type DC power jack and plug. The connectors are 5.5 mm x 2.1 mm in size with a positive center connection. The MED1 is compatible with other J2 LED




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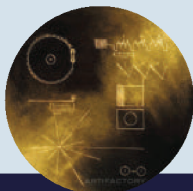
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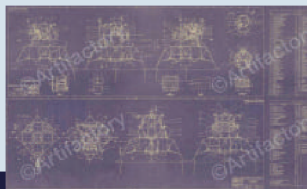
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# CONSTRUCTION OF A LOW BUDGET 180 MHz RF SWEEP GENERATOR

By Robert Reed  
rjr@ncweb.com

Post comments on this article and find any associated files and/or downloads at [www.nutsvolts.com/index.php?/magazine/article/december2013\\_Reed](http://www.nutsvolts.com/index.php?/magazine/article/december2013_Reed).



Sweep generators have a lot of uses in the design, prototyping, and troubleshooting of amplifiers, filters, and radio circuitry. They can greatly speed up these tasks by presenting many parameters at one time. The unit I'll discuss here was designed and built to fulfill my needs to do just that.

For starters, I would like to emphasize that this is a low budget generator — not a \$10,000 Agilent model — so a lot of concessions had to be made. In spite of that, this unit does a pretty decent job for general test bench use. I built it for just under \$50 in parts. Most of the common components came out of my junk box, but putting that aside you can still build it for under \$75, less the enclosure (I built mine from some scraps of steel and aluminum sheet material).

**B**efore I get into the theory of operation, I would like to discuss the background that led up to this arrangement. All of my designs were based on voltage controlled oscillators (VCO). Since it is difficult to get more than one octave of tuning range with the varactor diodes used in these circuits and still maintain fairly linear tuning, I decided that one octave would be my tuning range spec.

Since I use my function generator for all low frequency work (<2 MHz), I wanted a range of 2 MHz to upwards of 200 MHz of tuning. This would require a range of 100:1 — far more than a VCO could ever achieve. The only way to attain this range in one octave is to move it up into the VLF spectrum and then convert it down.

After doing some math, the optimum VCO would cover 300 to 500 MHz — a span that was easily obtainable, but also the start of a more expensive and complex device than originally planned.

The VCO signals would be fed into a mixer, along with a signal from a stable 300 MHz crystal oscillator. This produces (among other signals) a desired signal of fractional MHz to 200 MHz that could be made in one sweep. This had to be followed by a 200 MHz multipole steep sided low pass filter to reject any spurious signals that were produced in the mixer's heterodyne process.

Along the way, attenuator pads had to be installed: one 10 dB pad between the mixer and low pass filter to "eat up" all the reflected energy that was above the filter's pass band (these would have returned to the mixer in full strength, causing even more spurious heterodyne signal products); and another 6 dB mixer loss pad on the output to match it to a 50 ohm source, coupled with a 6 dB mixer loss. Quite a bit of amplification was necessary to make up for the losses. You probably can see

where I am going with this, as circuit problems were beginning to mount.

The unit performance was fair, but had serious flaws that could not be easily or cheaply overcome. Firstly, frequency stability was less than desirable. Secondly, tuning was very difficult to accomplish due to the high ratio of output frequency vs. tuning voltage.

To make this picture clearer, consider a VCO that tunes 100 MHz with a  $V_t$  (tuning voltage) of zero to 10 VDC. That's 10 MHz of frequency change for every volt applied, or 10 Hz per  $\mu$ V. Given a normal noise voltage of 200  $\mu$ V residing on the tuning line would result in a constant 2 kHz of jitter — before you even touched a front panel control.

But wait! It gets even worse. For wideband sweeping in the upper frequency range, the sweep tuning was somewhat acceptable, but let's say we wanted to look at tight 455 kHz or 10.7 MHz IF filters in the lower frequency ranges using a suitable

sweep width for these frequencies (100 kHz and 500 kHz, respectively). The setup became impossible. Just merely breathing on any controls and the tuning varied wildly and erratically. It was so sensitive that it was impossible to tune and completely useless on the lower end or any narrow band of spectrum anywhere else for that matter. It was at that point I decided to abolish this design. A new circuit was "born."

The new design breaks up the 180 MHz sweep into many one octave bands that offer satisfactory stability and tuning sensitivity to pick out any band of frequency and hone in on it precisely. This design uses 10 positions of a 12-position band switch — each position having generous overlapping bands of one octave. Due to its exceptional flatness of output, the switch can cover the whole spectrum almost as rapidly as turning a potentiometer. During this run-through, switching is stopped at points of interest and adjusted for closer observation.

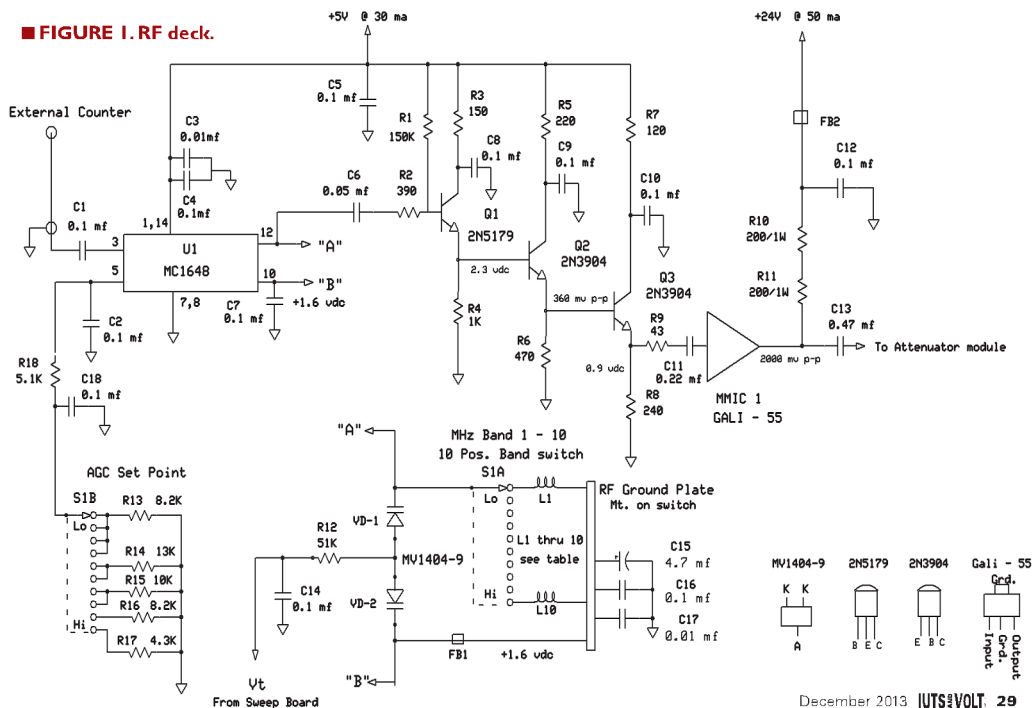
## Theory of Operation

Referring to **Figure 1**, the heart of this generator is the RF deck; it is based on a wonderful chip Motorola developed in the 1970s: the MC1648 — an ECL oscillator chip in a 14 DIP package with built-in automatic gain control (AGC). In fact, it has proven so popular it is still in current production, although these days it comes in a surface-mount package and goes under the name of MC100EL1648. These chips have a pinout for external LC

components tied to the oscillator section, but just "beg" for varactor tuning in place of a fixed capacitance. They are well-suited for VCO design from 100 kHz to well over 200 MHz (the SMD unit will work up to 1 GHz). The AGC works very well over a wide range of LC ratios and tank circuit 'Q's, but does have its limits.

For those of you that do not know, varactors are special diodes that use a reverse DC across their junction to vary the junction capacitance. The higher the reverse voltage, the lower the junction capacitance. This design

■ **FIGURE 1. RF deck.**



uses hyperabrupt diodes which generally produce the highest tuning ratio and best linearity, making them well suited for the tank circuit's capacitance in wideband VCO use.

Starting with the MC1648, the frequency of oscillation is determined by the inductor selected (band switch) and the capacitance of the varactors junction as set by the tuning voltage controls. The varactor tuning network of VD1 and VD2 gives the optimum tuning range and capacitance for a wide assortment of complimentary inductors to cover a 0-180 MHz spectrum. Tuning voltage is supplied by the sweep circuit through R12. The resonating inductance is selected via S1A — a continuous rotating 12-position wafer switch.

This switch requires a small modification which is the installation of an RF ground plate to its rear end (see under *Construction*). This is necessary due to the fact that pins 10 and 12 (A and B) have a +1.6 VDC bias on them. For this reason, the low end of the tank circuit cannot return directly to ground, but still must be maintained at RF ground potential via C15, C16, and C17. This is a "digitized" combination of capacitors (rather than a traditional 0.1 mf cap) that provides better RF grounding across a wide range of frequencies.

The RF ground plate also facilitates coil installation on the band switch. The RF ground plate must be returned to the MC1648 P10 by a lead connecting it to point B as shown in the lower center area of **Figure 1**. A ferrite bead (FB1) is added to this line to insure no RF is present on it.

Q1 provides a high impedance take-off point from the tank circuit, and R2 (known as a stopper resistor) keeps Q1 stable and prevents the possibility of spurious oscillation. Q2 and Q3 provide a generous amount of buffering and impedance transformation for driving the output amplifier MMIC-1. R9 gives a good 50 ohm match to the MMIC

(microwave monolithic integrated circuit) amplifier input.

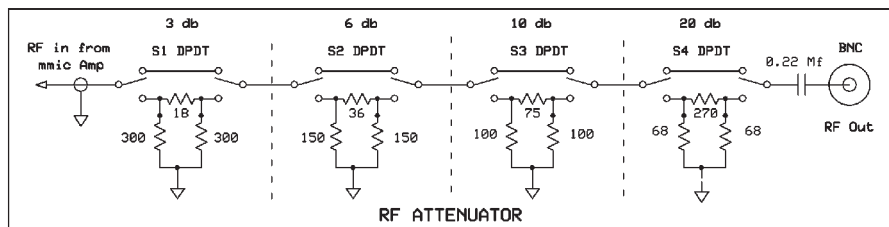
MMICs are wonderful little devices used as gain blocks with built-in 50 ohm input/output impedances. Their upside is high gain, high output, and wide frequency response (DC to > 4 GHz). The downside (at least for this application) is they require a relatively high voltage supply and consume a fair amount of power. I weighed these issues against a two-stage transistor amplifier fed from an eight volt supply, but for pure simplicity elected to go with this device.

The extra added 24 volt supply (transformer, filter, and regulator) takes up very little room and is quite cheap.

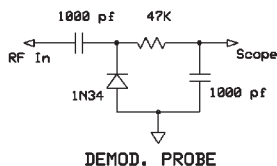
At this point and with all the circuit's signal levels adjusted properly, the RF output jack will display a clean sine wave of  $\pm 10$  dBm (2,000 mV P-P) with exceptional flatness of  $\pm 0.1$  dB, all the way up to 80 MHz (bands 1-8). Bands 9 and 10 (the highest bands) wander slightly from that figure but are still at a respectable  $\pm 0.7$  dB. This is due to the fact that we are pushing the limits here by outputting a 100:1 frequency range while mandatorily using the same values of the tuning cap in its tank circuit.

For any given frequency of oscillation, there is an optimum L/C ratio. We are at the point of exceeding those limits as the Q of the tank circuit drops to a low value at the upper frequencies (i.e., we would desire less capacitance and more inductance on the higher ranges to maintain optimum Q, but the minimum capacitance is limited by VD1,2).

This circuit uses a range of 80  $\mu$ H to 20 nH. A ratio of 4,000:1 and the tank Q varies considerably throughout the total frequency range, which affects the tank circuit's RF amplitude — also putting a strain on the AGC to keep up with it. Between the MMIC amp and RF output jack, an attenuator is desired to gain some amount of output signal level control. However, commercial step attenuators are extremely expensive (\$150-\$1,200) and continuously



All Switches are DPDT miniature Toggle



■ FIGURE 2. Attenuator and demod probe.



variable ones are even harder to come by.

I decided to build a compromise attenuator (as shown in the lower middle of **Figure 2**) that would give 39 dB of attenuation (~100:1) and a resolution of about 3 dB increments, and yet still keep attenuator costs to an acceptable level. The four step attenuator filled this requirement and should be adequate for most testing.

The sweep board shown in **Figure 3** is where all the required VCO tuning voltages (Vt) are derived.

For use as a stand-alone CW (continuous wave) generator, the sweep portion is turned off by virtue of setting the Dispersion switch S2 to its CW position. Now, VCO tuning is done manually by the Main & Vernier tuning controls (P5 and P4). These are fed from the divider network of R25, R26, with a generous amount of filtering (we want this line to remain very quiet with respect to electrical noise). These controls output a DC voltage of -0.3 to -5.0 volts, and are also used to set the sweep start frequency when entering 'sweep mode.'

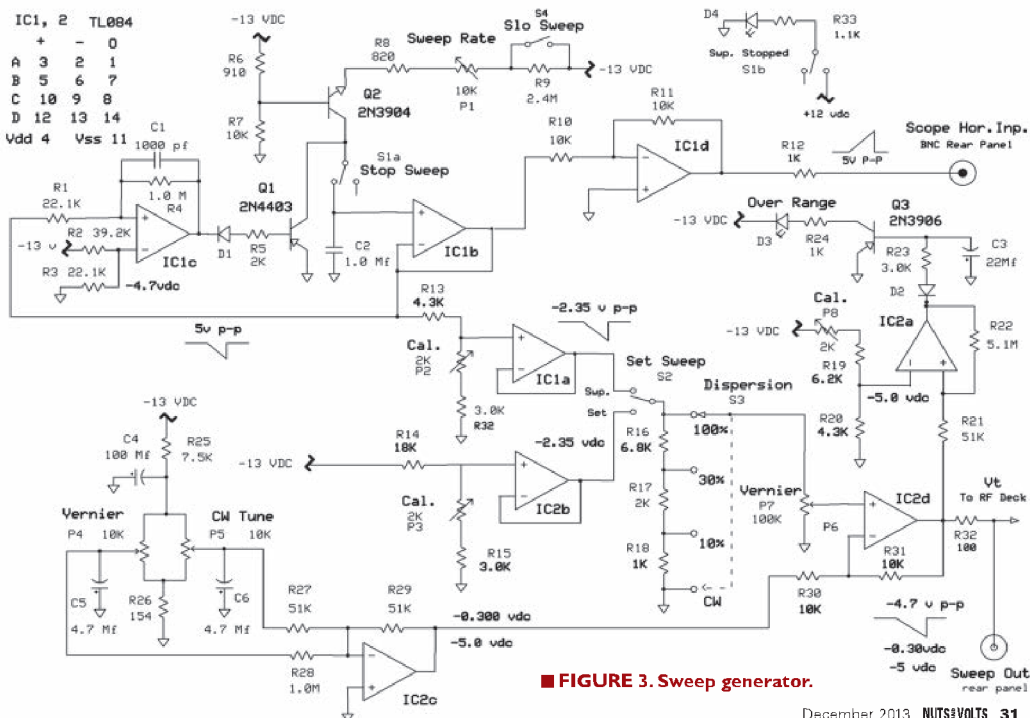
Actual sweep voltage is derived from a very linear ramp voltage produced across C2 and fed to the input buffer IC1B. The ramp is generated by a constant current source (Q2) feeding C2. The rate of that ramp is controlled by R8

and P1 — about 10 Hz to 100 Hz.

Opening S4 (SloSweep) introduces R9 into the circuit, producing a very slow rate of 20 seconds (more on this later). Without further control, C2 would just keep charging until it reached -13 VDC and sit there forever, so it needs to be reset periodically; that is the job of IC1C and Q1. This is a comparator circuit set to trigger at approximately -5.5 VDC. The actual level is not that critical but repeatability of its trip point is hence the 1% metal film resistors used here — not for accuracy, but for stability.

R4 adds a small amount of hysteresis for noise rejection and consequent jitter. C1 is very important to hold the output reset voltage long enough (about 20  $\mu$ s) to allow Q1 to completely dump the charge on C2, and then the whole charging process repeats itself. IC1B's output feeds off in two different directions: an inverting amp (IC1D) with a gain of one to drive an oscilloscope's horizontal or 'X' axis; and the other to a calibration pot (P2) for setting the exact amplitude of the ramp voltage into IC1A. IC2B outputs a DC voltage of the exact level that matches the peak amplitude of the ramp voltage coming out of IC1A. This level is calibrated by P3.

The Set Sweep switch (S2) is used for setting the



Frequency Span	2 MHz to 180 MHz in 10 bands with a 25/30% overlap.
Frequency Stability	Better than 200 ppm after warm-up.
RF Output	+10 dBm (2,000 mV P-P) of clean sine wave into 50 ohm termination.
Output Flatness	$\pm 0.1$ dB 2 MHz to 80 MHz; $\pm 0.7$ dB 70 MHz to 180 MHz; 50 ohm term.
Attenuation	39 dB (approx. 100:1) in 3 dB steps.
Sweep Linearity	@ 100% sweep <1-2 % error    @ 10 % sweep < 0.2 % error

**Table 1.**

S3 — a four-position range switch to allow coarse adjustment of the sweep or frequency dispersion. P7 is the fine adjustment of the range selected, and feeds IC2D.

As mentioned earlier, CW tune and Vernier are for manual tuning or sweep start frequency. These two control voltages are summed in IC2C and fed to IC2D where they are summed with the ramp voltage. That output (Vt) is then sent to the VCO on the RF deck for biasing the varactors. The output of IC2D has an intended range of -5.0 volts; more specifically, -0.3 to -5.0 volts to manually tune one complete octave for the band selected. Its output may also contain a ramp voltage of 0 to -4.7 P-P.

When a -4.7 volt ramp is added to the minimum CW voltage of 0.3 volts, we have a range of -0.3 to -5.0 volts — exactly the same as the manual tuning voltage range and the optimum tuning voltage range required by the VCO. So, we can sum any combination of CW and ramp voltage that will stay within that -0.3 to -5.0 voltage range. Since (obviously) we could easily sum both of them to a level that would not only drive the VCO out of its linear range but also drive IC2D into saturation (producing a flat spot on the sweep ramp and giving erroneous readings on a CRT trace), this is a no-no! So, how would we ever be aware this is happening?

That is the job of comparator IC2A to warn us of this situation. Its trip point is set for about -5.2 volts. When this level is reached, the trip level drives Q3 into saturation which, in turn, lights D3 (labeled 'Reduce Freq' on the front panel). You'll see a slow flashing at first, then a constant on. Since the very peaks of the ramp in the tripping mode are of such short duration, they would not hold the comparator on long enough to see any visible light from D3. Capacitor C3 was added to give adequate hold time for these short duration trips.

The calibration pot P8 sets the level of the trip point. One feature I added that is optional is the 'Stop Sweep' Alert LED D4 at the upper right of **Figure 3**. The original Stop Sweep switch was changed from an SPST to a DPDT (S1A and S1B) with an LED added to the second pole. Now when the sweep is stopped, the LED lights up and alerts me to this.

There were times (that for the life of me) I couldn't figure out why the generator was not working properly, when it would finally dawn on me that the sweep was in the stopped position. Now, the LED alerts me to that

situation every time. The Stop Sweep switch S1A is used in conjunction with the SloSweep switch S4 for marking frequency. I used this method rather than a traditional marker generator which adds a lot more circuitry, expense, and sometimes a lot of confusion. More on this later.

The generator's final specifications are shown in **Table 1**.

## Construction

I built the internals in three separate modules so that each could be separately tested before installing in the chassis: the RF deck, sweep board, and power supply. The RF deck was built on a 2" x 2.5" single-sided circuit board in typical RF prototype fashion. **Figures 4** and **5** show the bottom and top views, respectively.

First, I draw out all the components on a sheet of quadrille graph paper with each intersection representing 0.1" spacing. All components are included — both top and bottom mounted. These are drawn as you view the top of the board, but also using 'X-ray' vision to see the bottom (copper side) of the board.

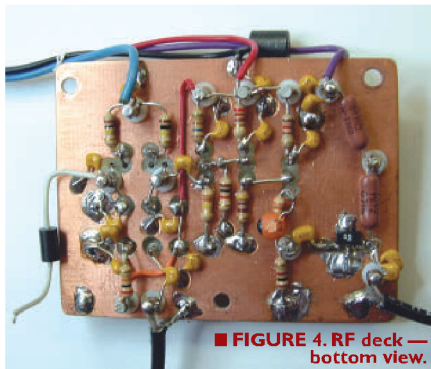
After completing the layout on graph paper, the hole locations are transferred to a scrap of perf board of the same dimensions as the actual circuit board and held in place with double-sided tape. This also makes a nice drilling guide for a clean appearance. Ideally, use a #56 drill (0.040"), but lacking that you could go as large as 1/16".

After drilling is completed, clean out the copper side of the holes for components that do not go directly to ground by hand spinning a larger drill bit. This opens up the copper foil to give adequate insulation around it; about 1/8" is sufficient. **Figure 4** gives you a general layout scheme.

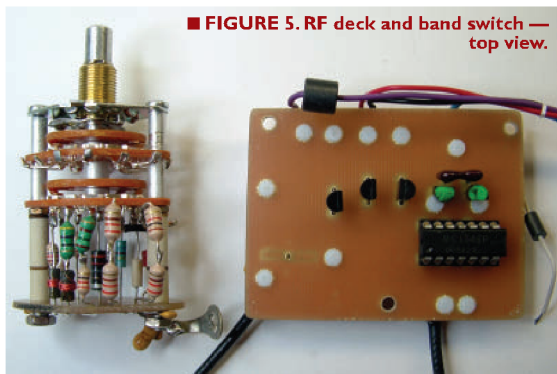
After the active through-hole components are inserted, their leads are used as solder tie points. All other circuit nodes above ground are soldered to insulated standoffs (the white dots in **Figure 5**) and, of course, the grounded components are soldered directly to the ground plane. The layout is pretty straightforward and follows the signal flow as shown back in **Figure 1**.

If you have never worked with RF frequencies before, two rules are paramount. First, a ground plane type of construction as used here is mandatory; the other is to keep component leads as short as possible. There is an old saying among RF design engineers: "If you can see the leads, they are too long."

A few other things to mention are the MMIC amplifier is an SMD device and is located in the lower right of **Figure 4**. It required two "islands" to be ground out for its input and output terminals; these were the only islands needed on this board. The other is that two insulated standoffs were mounted close to the MC1648 P10 and



■ FIGURE 4. RF deck — bottom view.



■ FIGURE 5. RF deck and band switch — top view.

P12 connections (A and B). This is for connecting to the band switch which will eventually end up sitting right over the top of them. They are located in the middle left of Figure 4 and are a little hard to see. Pin 10 already has its lead installed with a ferrite bead in place.

Lastly, the MV1404 varactor diodes I used in this particular project came in TO-92 packages which are becoming very hard to find. They were later replaced with an MV 1404-9 which is a dual diode unit in a single SMD package. It also improved performance slightly.

The 12-position band switch shown in Figure 5 is made up of a two-pole, double-deck 12-position wafer switch.

The first deck is used for AGC level resistors. Cut a piece of single-sided circuit board a little larger than the size and shape of the switch deck. Drill two mounting holes for attaching to the switch bolts and ream out the copper side to provide an insulating barrier. Drill 12 small holes in a slightly larger circle pattern than the switch contact points. Remove the switch bolts one at a time and replace with 2.5 mm x 2" screws (4-40 thread will work but requires a small amount of reaming to pass through).

Nut these down to the switch, then install two spacers of approximately 1" length on the protruding bolts. Install the previously made up circuit board with the copper side to the rear. Drop a couple of insulating washers over the bolts and nut down the assembly firmly (don't go crazy here). This newly added circuit board is the RF ground plate shown as such in the schematic.

The coils are mounted by shoving one lead through the ground plate hole and then cutting the other lead to length; merely lay it on its associated switch lug and solder. Solder the end protruding through the ground plate and trim off the excess. Then, continue to the next one until finished.

Installing band's 9 and 10 coils adjacent to the wiper contacts will alleviate some of the switch's parasitic reactance which becomes more dominant at these higher frequencies. The chart in Table 2 shows the band

and associated coil value.

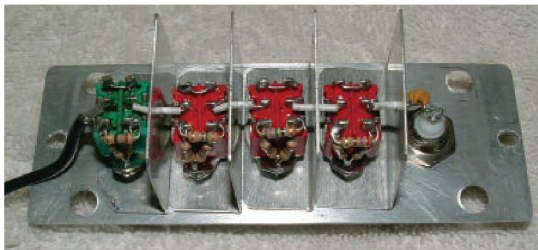
Given the tolerance on these coils, the labeled band frequencies are very nominal but will be in the ballpark for a guide. All bands have sufficient overlap so that no voids will occur. (Some of these coil's values may be unobtainable due to being out of stock or on back order, but they can be made up in series with other values — just add up values in the same way as series resistance.)

Solder a piece of #22 solid hookup wire about 3/4" long to the wiper contact. Now when this switch is installed, that lead will be at the bottom of the switch and positioned directly over the area of the MC1648 P12 or stand-off. Note that the RF deck is mounted upside down and directly under the band switch. This switch is mounted 1-1/4" (shaft center) above the RF circuit board surface.

You can panel mount it, or do as I did and mount the RF deck and switch to a scrap of 1/32" aluminum bent at a 90 degree angle. This can then be powered up for basic checkout before the whole sub assembly is installed in the enclosure. This method facilitates checkout as a stand-alone sub assembly and was mandatory in my case for the design process. The sweep circuit was built on a RadioShack 276-168B circuit board. I love these little boards as they accept DIP devices very nicely. The board measures 2-1/4" x 2-1/2". Layout is straightforward and non-critical; although, I added a 16-pin header due to a multitude of lead connections to the front panel controls. Also, do not use a ceramic capacitor for C2 — mylar is best!

Band 1	2 - 4 MHz	80 uH	Band 3	5 - 10 MHz	12 uH
Band 2	3 - 6 MHz	33 uH	Band 4	8 - 16 MHz	4.7 uH
Band 5	12 - 24 MHz	2.2 uH	Band 8	40 - 80 MHz	0.18 uH
Band 6	20 - 40 MHz	0.82 uH	Band 9	60 - 120 MHz	65 nH
Band 7	30 - 60 MHz	0.37 uH	Band 10	90 - 180 MHz	20 nH

**Table 2.**



■ **FIGURE 6. Attenuator.**

Generally, I only take a circuit's power requirements back to the voltage and current requirements needed, and leave it up to the builder to rummage through their junk box for the parts necessary to complete the raw voltage supply. Since this project includes an odd assortment of voltages, I am including a **schematic** for it. The circuit is so simple and straightforward that no explanation is really needed here. Hence, no parts list was written up for it. However, the transformers will appear in the overall parts list, and they are quite small and cheap.

Also, you may be wondering about the -13V supply. I wanted a  $\pm 12\text{V}$  supply for the op-amps. The negative supply is used as a reference voltage at many points on the sweep generator board (**Figure 3**). Since the 79L12 can vary by almost a volt either way in tolerance, I wanted to make sure I had a specific voltage at this point. This simplified the design and will always insure that it can maintain that voltage — even if replacement of that

regulator was required. The regulator voltage can be adjusted up by virtue of its common pin resistor, but you can never make it lower. So, by adding resistance to that pin, a -13V output will always be obtainable — no matter what the regulator's tolerance is. The 79L12 I used required a 510 ohm resistor to output exactly -13.0V. The 79L12 you use may have a different tolerance and will require a different value. Shoot for 1% of the target voltage — not difficult to do. The attenuator is shown in **Figures 2 and 6**.

As you can see in the **photo**, I built mine on a shielded panel that gets enclosed in a box. This was probably overkill as 40 dB of attenuation is not that great. I think the switches could merely be panel mounted and spaced on 5/8" centers without any shielding and perform just fine. These use garden variety miniature toggle switches and 5% 1/4 watt resistors. I have had decent performance in the past with this type of construction in upwards of 200 MHz frequency. This one checked out with a worst case error of 3%. Note that the top two attenuator switches shown on the front panel look a little odd. This was a temporary change I made to facilitate a battery of repetitive tests I am making, and normally these would be side to side toggles as the lower two are.

**Figure 7** shows the internals and can guide you as to overall layout. I built the chassis by forming a 90 degree bend in a piece of 1/8" aluminum sheet stock. Four 3/4" aluminum L brackets were cut and mounted to this piece for attaching the front panel and cover. The front panel was cut from 1/16" aluminum sheet and fastened to the two front brackets with two 6-32 screws. The cover was a piece of 20 gauge steel sheet with two 90 degree bends that was attached to the side brackets with four 6-32 screws.

The front panel layout points and artwork were made using a free program from Front Panel Express ([www.frontpanelexpress.com](http://www.frontpanelexpress.com)). See my power supply article in *Nuts & Volts*' March 2007 for more detailed info on these procedures.

## Calibration and Usage

For the following tests and procedures, an oscilloscope and frequency counter are required. Starting with the RF deck, ideally you will want three voltages to coincide with those shown in **Figure 1**. Since Q1, Q2, and Q3 are DC coupled, the DC current through R4 sets these levels. You want to be as close to 2.3 VDC here as possible by selection of the value of R1. This could be quickly done on a solderless breadboard with the intended transistor used.

The next point to check is the signal level at the Q2 emitter. This should be within 5% of the 370 mV P-P value as shown back in **Figure 1**. Minor changes in R13-R17 (AGC) will set this if necessary for those particular bands.

Finally, the signal level at the C11, R9 junction should be 185 mV P-P. Make these tests at 2 MHz with your



■ **FIGURE 7. Internals.**



scope's 10:1 probe. If all levels are correct, you should see 2,000 mV P-P at the RF output jack with no attenuators switched in and terminated in 50 ohms. The MMIC's gain is about 21 dB.

On to the sweep board. Attach a DMM to the output of IC2B (S2 throw) and adjust P3 (DC calibration pot) for exactly -2.35 VDC. Display that level on one channel of a properly calibrated oscilloscope. On the other channel, display the ramp voltage from the output of IC1A (the other throw of S2). Adjust P2 (ramp calibration pot) so that the P-P ramp level exactly matches the -2.35 VDC level.

Now, the Set Sweep switch compares a DC voltage to the ramp's peak amplitude regardless of the adjustment of Dispersion switch (S3) or Dispersion level (P7). This allows for a stable frequency reading when setting the dispersion or sweep stop point frequency. When the Set Sweep switch is flipped back to its sweep position, the ramp's peak will always equal that DC set point and consequently sweep the frequency to that exact setting.

Remove the scope probes and attach one probe to the output of IC2D. Adjust CW main to obtain two or three volts DC here, then turn up the ramp amplitude until the combination of the two equals -5.0 volts at the ramp's negative peak. Adjust calibration pot P8 until LED D3 just starts to flash. This is the alert signal of exceeding the maximum range of linear tuning voltage. This completes calibration.

At this point, a brief explanation of the front panel controls is in order. With the Dispersion switch (S3) set at its CW position, the Main Tune control will manually tune one octave of frequency for any band selected. This allows the unit to be used as a common CW signal generator. The Vernier tuner (P4) which normally sits at its midpoint position allows a  $\pm 2\%$  shift for fine adjustment.

In Sweep mode, the Start Sweep frequency is adjusted as just explained. Switch the Dispersion Range (S3) to an applicable position and S2 to the Set Sweep position and adjust the Dispersion level (P7) to the desired sweep upper limit frequency. Any value of zero to one octave of sweep can be achieved, depending on the start and stop frequency adjusted by these controls.

Place S2 back in Sweep for sweep operation. The Sweep Rate control (P1) will allow sweep rates of 10 to 100 Hz, and is adjusted for the best CRT presentation. Normally, the faster rates are desired, but for tight filters it will have to be slowed to reduce distortion. The SloSweep mode switch S4 (mine is attached to P1) is used in conjunction with the Stop Sweep switch. This produces a slow moving dot across the CRT screen that can be stopped at any point by operation of S1. This effectively makes IC1B a sample and hold circuit, and will maintain that dot position for several minutes before any noticeable movement of that dot occurs.

In actual testing, impedance matching will insure accurate results, but if the input and output to the device

under test (DUT) have adequate isolation then a decent test can be accomplished. Two example tests may make the usage a little clearer:

**Example 1** — To test the resonant frequency of an 8.5 MHz parallel resonant circuit, set the generator to full sweep at 5-10 MHz (band 3). Feed a signal into the DUT of the desired level through adequate isolation. Connect the scope's vertical input probe to the output of the DUT. Connect the scope's horizontal input to the Scope Horizontal jack from the generator and adjust for exactly 10 graticule divisions of trace. We are now sweeping at 500 kHz per graticule division (5 MHz/10 divisions).

You will see a definite peak in voltage as the trace travels across the screen. Let's say it peaked at seven graticule divisions; the resonant frequency is 8.5 MHz (sweep start frequency at 5 MHz plus seven divisions at 500 kHz per division). The sweep rate can be slowed to 20 seconds with S4 (at this point, the horizontal trace will be a slow moving dot rather than a solid line), and the moving dot will stop right at its peak with the Stop Sweep switch (S1A) and the exact frequency read from the Counter Output jack.

Similarly, the dot can be stopped at the -3 dB point (bandwidth) or any unusual aberrations for marking frequency. The dot may be stopped anywhere along the horizontal axis to mark frequency.

**Example 2** — You may want to check out the frequency response of the wideband amplifier you just prototyped. Start with the lowest band at 100% sweep and just rotate the band switch as you would a potentiometer. Stop at the -3 dB point, also noting any unusual events along the way. You can go to SloSweep to mark the frequency at any points of interest.

Due to the generator's exceptional flatness of amplitude, switching through the bands always maintains the same input level for accurate test results. At first, these controls and their interactions may seem a overwhelming but I guarantee you that after a few hours of playing with them on the test bench, they will become "old hat."

## Closing Notes

The above test examples were very basic just to familiarize users with the operation of this generator, but far more involved tests really will make a sweep generator appreciated as to its ability to gather info in a short amount of time. That part I will leave to the builder to gain more knowledge from the Internet and other sources.

I wish I had more space to go into more detail on all the different aspects of this project, but since I don't I have included several websites in the **Parts List** that contain a wealth of information.

So, there you have it. There are a lot of variables here. You can build this generator exactly as described or add bands (two vacant switch positions are still available), delete

# PARTS LIST

All resistors are 1/4 watt 5% unless otherwise noted. \*Asterisks denote 1/4W 1% metal film.

## RF Deck:

R1	150K
R2	390 ohm
R3	150 ohm
R4	1K
R5	220 ohm
R6	470 ohm
R7	120 ohm
R8	240 ohm
R9	43 ohm
R10, R11	* 200 ohm 1 watt \$0.15
	Vishay-Dale CMF60200R00HEK

C1-C2, C4-C10, C12,	
C14, C16, C18	0.1 mfd
C3, C17	0.01 mfd
C11	0.22 mfd
C13	0.47 mfd
C15 tantalum	4.7 mfd

## Sweep Generator Board:

R1, R3	*22.1K
R2	*39.2K
R4, R28	1.0 meg
R5, R17	2K
R6	910 ohm
R7, R10, R11,	
R30, R31	10K
R8	820 ohm
R9	2.4 meg
R12, R18, R24	1K
R13, R20	4.3K
R14	18K
R15, R23	3.0K
R16	6.8K
R19	6.2K
R21, R27, R29	51K
R22	5.1M
R25	7.5K

## Power Supply:

T1	120V/24V c.t. @ 85 mA	SB3512-2024	\$4+
T2	120V/30V c.t. @ 55 mA	SB3518-3030	\$4+
T3	120V/18V c.t. @ 65 mA	SB2812-2018	\$3

MC1648 and MC100E 1648 datasheets are easily obtained through Google and have a lot of good information. DIP version available at [www.elexp.com](http://www.elexp.com) (Electronix Express). Most major distributors carry the MC100EL1648.

MMIC-1 is available at [www.minicircuits.com](http://www.minicircuits.com). Ordering can be done directly. Also, lots of downloads for info.

MV1404-9\* is available through Arrow Electronics. Datasheets are on the Web.

FB1	J.W. Miller	FB43-226-RC	\$0.15
FB2	J.W. Miller	FB43-287-RC	\$0.15

L1-L10 See text chart for values  
Conformally Coated, Faston, or Xicon

U1	(14 DIP)	MC1648	\$7
U1 (alternate)	MC100EL 1648	(SMD)	\$10
MMIC	Mini Circuits	GALI-55	\$3
Q1	2N5179		
Q2, Q3	2N3904		
VD 1,2	MV1404-9 (varactor diode)		

RF Band Switch (S1) Alpha SR2921F-12S \$4+  
Alpha also carries a line of low priced potentiometers used in this project.

R26	150 ohm
R32	100 ohm
R33	1.1K

C1	-0.001 mfd
C2	1.0 mfd Not ceramic or 'lytic
C3	22 mfd 'lytic
C4	100 mfd 'lytic
C5, C7	4.7 mfd tantalum

D1, D2	1N914
D3	10 mA LED red
D4	10 mA LED amber

Q1	2N4403
Q2	2N3904
Q3	2N3906
IC1, IC2	TLO84

Band switch S1 available at Mouser (Mouser# 105 prefix). Also the line of Alpha pots are quite cheap here.

Coils L1-L10 and ferrite beads available at Mouser and Digi-Key.

Tamura transformers T1, T2, T3 available at Mouser and Digi-Key (Mouser #838 Prefix).

All catalog nos. are Mouser.

\*MV1404 - 9 is subject to availability. If you have trouble, I do stock this item.

Problems? Email me and I can walk you through most of the construction and design. I have more supporting info that you may use.

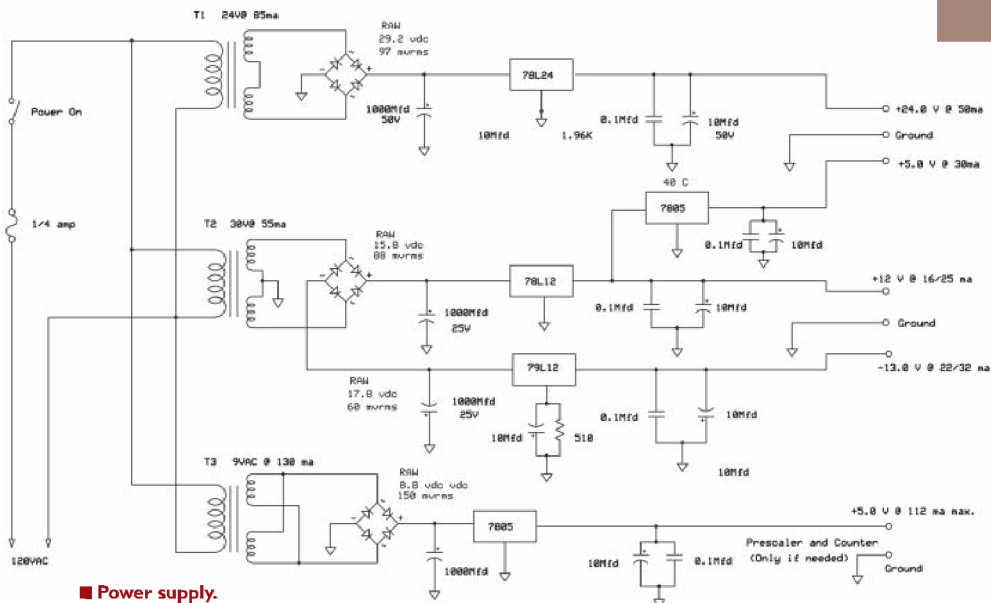
bands, or even hopscotch bands that suit your particular interests. Or, maybe just use the RF deck or sweep board to adapt into different designs of your own.

RF loves surface-mount technology, so if you are into this all the parts are available in SMD packages (of course, the MMIC amplifier and varactor diode already are).

I have also included a schematic of a detector probe back in **Figure 2** that can be used to give an envelope display rather than an RF presentation on the CRT. However, it requires a high level of detection for good linearity. Fair linearity can be obtained in the 100-1,000 mV range. I did add ventilation holes in the enclosure so that

the unit reaches thermal equilibrium in a shorter time period. Future plans call for an active detector probe so as to drive the detector diode at a higher level for improved detection linearity.

The completed generator is shown with its own internal frequency counter and prescaler, but these were omitted in the internals picture of **Figure 7** for clarity (although I kept the optional supply in the power supply schematic). Unfortunately, space does not permit for that construction since it would be a complete article in itself. If there's enough interest, the editors may be open for a follow-up article on the design and construction of that. **NV**



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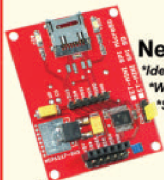
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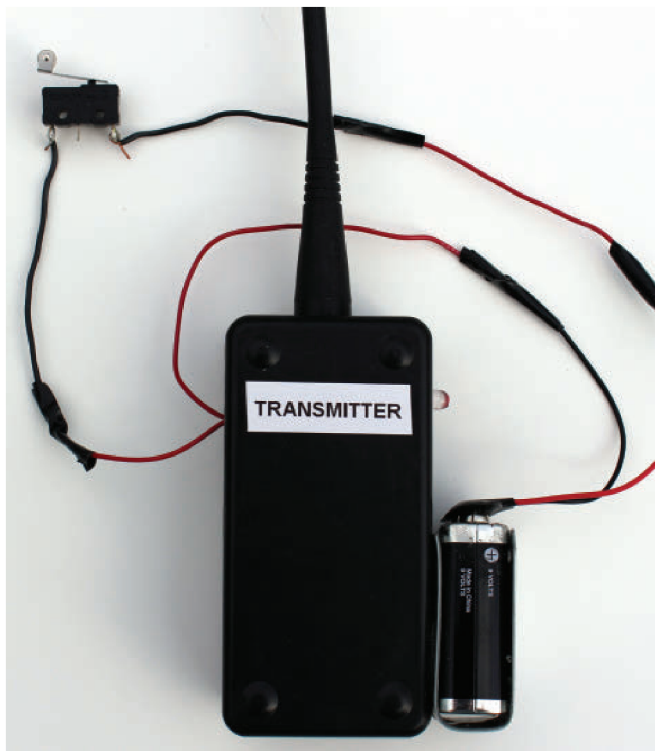
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# BUILD A WIRELESS SILENT ALARM WARNING SYSTEM

By Roger Secura  
rsecura@ix.netcom.com

Post comments on this article and find any associated files and/or downloads at [www.nutsvolts.com/index.php?/magazine/article/december2013\\_Secura](http://www.nutsvolts.com/index.php?/magazine/article/december2013_Secura).



Here's an inexpensive wireless warning system you can build in one night. Since the silent alarm can't irritate your neighbors, the transmitter and receiver pair can be used as a garage, barn, shed, mailbox, freezer, window, or door open alert, for example. Just place the receiver unit in your living room, kitchen, or bedroom, and it will signal you (flashing LED) if something was left open. The range between the transmitter and receiver is about 200 feet indoors and is further outdoors.



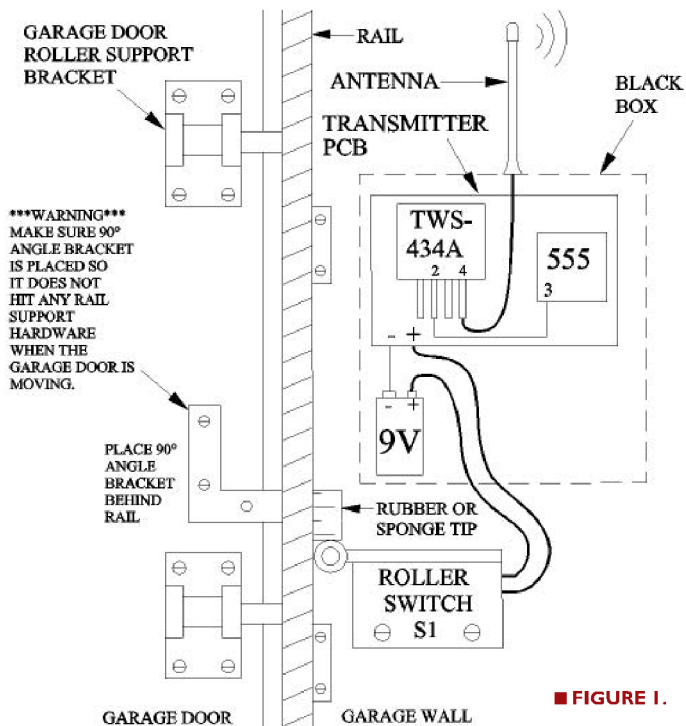
## How It Works

Figure 1 and Figure 2 are block diagrams of the transmitter and receiver circuits.

Inside the transmitter black box (in Figure 1) is a 555 timer configured so that it operates in the astable mode. The 555 sends a constant stream of square wave pulses to the Rentron 434 MHz TWS-434A RF transmitter chip. Note in the diagram that there's no power (+9V) to the transmitter circuitry as long as switch S1 is closed (i.e., door closed).

Power is only restored to the circuit when the roller switch (S1) arm is open (i.e., door open). That means the 9V battery should last at least a year or so.

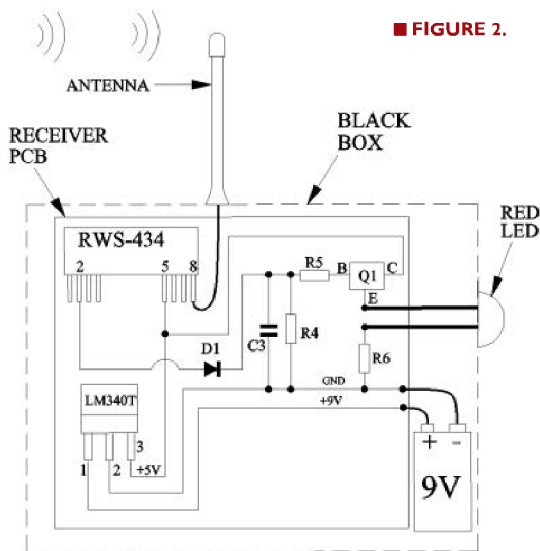
The RWS-434 integrated



■ FIGURE 1.

## PARTS LIST

ITEM	QTY	DESCRIPTION	PART #	SOURCE
S1	1	Roller Lever Switch SPDT	275-0017	www.radioshack.com
IC1	1	555	555	www.mouser.com
IC2	1	RF Wireless Transmitter	TWS-434A	www.rentron.com
IC3	1	RF Wireless Receiver	RWS-434	www.rentron.com
Antenna	2	6.5" Antenna	RA-ANT	www.rentron.com
Battery	2	Nine volt	N.A.	
VR1	1	Voltage Regulator	LM340T (7805)	www.mouser.com
LED1, LED2	2	LED, Red, water-clear dome, Ultra-Bright, 640 nm, through-hole	604-WP1503SRC/F	www.mouser.com
Q1	1	NPN Transistor	2N2222	www.mouser.com
D1	1	Diode	1N4001	www.mouser.com
R1	1	100K Resistor	N.A.	www.mouser.com
R2	1	10K Resistor	N.A.	www.mouser.com
R3, R4, R5, R6	4	1K Resistor	N.A.	www.mouser.com
C1	1	4.7 $\mu$ F Electrolytic Capacitor	N.A.	www.mouser.com
C2	1	.01 $\mu$ F (103) Capacitor	N.A.	www.mouser.com
C3	1	33 $\mu$ F Electrolytic Capacitor	N.A.	www.mouser.com
<b>HARDWARE</b>				
Black Box	2	Project Enclosure	270-1802.	www.radioshack.com
PCB	1	Dual Printed Circuit Board	276-159	www.radioshack.com
PCB	1	Dual Printed Circuit Board, 417 holes	276-150	www.radioshack.com
Snap Connectors	2	9V Battery Snap Connectors	270-0325	www.radioshack.com
9V Battery Holder	2	9V Battery Holder	270-326	www.radioshack.com
Angle Bracket	1	Flat Corner Brace, 90 angle, 2-1/2"	339 369	Home Depot
Screws	4	size — as needed	N.A.	Home Depot
Velcro Strip	2	3-1/2" x 3/4"	90076	Home Depot
Hook-up Wire	N.A.	24 AWG Solid Wire	N.A.	www.mouser.com



■ FIGURE 2.

receiver chip in **Figure 2** picks up the transmitted signal from the antenna. This RF signal is then fed into a passive demodulator circuit (diode, cap, and resistor) to remove some of the radio frequency elements from the data signal. This cleaned-up data signal is delivered to the base of transistor Q1.

In turn, the LED on the receiver board will continuously blink until the transmitter stops sending a signal. In other words, the LED will stop flashing when (for example) a garage door is closed and the roller arm on switch S1 is closed.

It's important to note that both the transmitter and receiver circuits (see the schematics in **Figure 3** and **Figure 4**) are powered by 9V batteries. However, the RWS-434 receiver IC in **Figure 4** requires a 5V power supply. This is where the ubiquitous 7805 voltage regulator comes into play.

## Assemble It

Take a couple of screws and attach the roller

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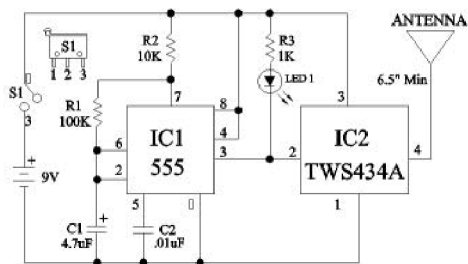


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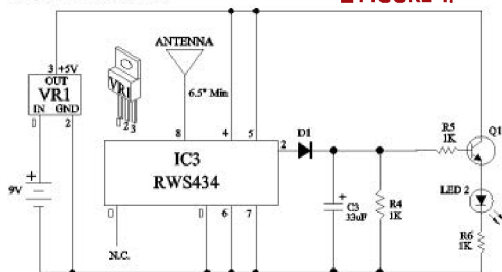
TRANSMITTER CIRCUIT

■ FIGURE 3.



RECEIVER CIRCUIT

■ FIGURE 4.



switch S1 to the wall as shown in **Figure 1**. Attach the 90 degree angle bracket to the garage door with a couple of screws so that when the garage door is closed, the roller arm on switch S1 is also closed.

Make sure the bracket can move freely. Also, attach the transmitter black box to the garage wall with Velcro™ or screws.

## Final Note

The TWS-434A transmitter chip and the RWS-434 receiver chip cost less than \$10 each. Certainly, some piece of mind is worth that. **NV**

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# *My Christmas Can Light Dimmer*



A few years ago, I decided to replace my incandescent lights with the new LED versions that were available. However, one trip to the store to price out the lengths of lights I would need sent me running for the door. I would be using my incandescent icicle lights a few more years. I just hoped they would last.

I remembered reading an article that stated if you reduce the voltage to an incandescent bulb by ten percent, you can double its life. Certainly, I could figure out some method that wouldn't break the bank ...

I present to you my "brilliant" solution: the Christmas Can Dimmer.



**I**t was time to put my lights on a voltage diet, so I came up with a very simple method. I would add a dimmer to the lighting scheme. I housed the dimmer in an “approved” water-tight enclosure, and was able to take the voltage down by 10 %. The first generation of “lights on a diet” was born.

It has been a few years now, and I have found that my voltage diet works very well. I seldom lose more than one bulb a year.

This year, I decided to carry my idea indoors. I needed some sort of container that would blend in with my indoor decorations. I decided to fabricate one using a recycled aluminum can.

I started by scoring a line (with a marker) around the circumference of a can one half inch above the height of

the dimmer I was using (**Figure 1**). Using a hack saw and a pair of metal snips, I reduced the can size appropriately (**Figure 2**). When performing this task and others like it, always use gloves and eye protection! Metal shards can cut skin and do eye damage.

Once the can was cut, I took a file and removed any sharp edges. The next step was to make a hole in the top (dead center) to facilitate the dimmer shaft. I rounded the “dimmer ears” to fit the can (**Figure 3**). I then painted the lid and the rest of the can in a “Christmas” green. I removed the dimmer knob and painted it red.

I made a hole for the wiring. I used a standard Romex type connector to act as wire protection. The Romex nut secures the connector to





**Figure 4B.**

the can (**Figures 4A and 4B**).

Wiring was simple: A two-prong male (polarized) AC plug was installed on a piece of “zip” (lamp) cord; the end was run into the container. Likewise, a two-prong female (polarized) receptacle was attached to a piece of zip cord, and its other end run into the container. One end of each zip cord gets attached to each other and run to the ground lug.

*Make sure you check connections (with a meter or other tester) to ensure the male large ground plug blade is connected electrically to the Romex ground screw!*

The remaining two leads go to the dimmer (via wire



**Figure 5.**



**Figure 6.**

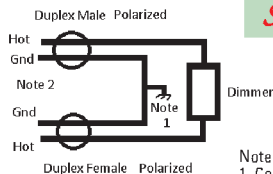
nuts). The **schematic** and **Figure 5** detail the connections.

Now, the dimmer can be inserted and the can lid put in place to seal the enclosure (**Figure 6**). Once this was done, I hammered the lid all around to seal the enclosure further. I used a quick spray of paint to touch up some paint chipped in the sealing process, I put the knob in place, and my “Christmas Can Dimmer” was complete.

Here’s how to implement my solution: Plug the male into an AC outlet. Put the Christmas lights into the female receptacle. Now, bring up the dimmer to full brightness.

Once you have reached full brightness, turn the dimmer counter-clockwise to take the lights down approximately 10 percent. You can use a meter to adjust the voltage to 90 percent of full value (if you want to be more precise).

You will not only enjoy years of trouble-free lighting, but your lights will have additional ambience, as well. **NV**



**Schematic.**

Notes:  
1. Connect Gnd. Wire to Romex connector screw.  
2. Large pin on male and female is Gnd.

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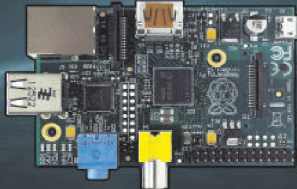
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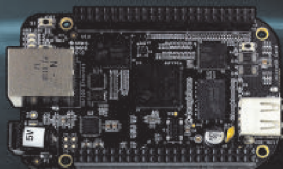
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# THE GOOD THE BAD AND THE HexBright



Nuts & Volts first met Christian Carlberg back in 1997, when he brought walking robots armed with rotating rip-saws to the San Francisco cult fighting competition known as Robot Wars. His walking robots (see [www.youtube.com/watch?v=W-bTuez6ajl](http://www.youtube.com/watch?v=W-bTuez6ajl)) were unique to an already very unique event that drew a variety of interesting competitors from Will Wright (creator of the Sims video game) to most of the MythBusters gang. Christian came back on our radar screen with a Kickstarter project — HexBright, the Arduino flashlight — that finished in the top 10 most funded projects of all time and has since turned it into a cottage tech industry. The following is some of his background and advice for other garage entrepreneurs.



# Shedding Some Light on Kickstarter



By Christian Carlberg

Post comments on this article at [www.nutsvolts.com/index.php?/magazine/article/december2013\\_Carlberg](http://www.nutsvolts.com/index.php?/magazine/article/december2013_Carlberg).

## Brief History

I was very flattered when *Nuts & Volts* asked me to write this article. In a small but critical way, this magazine changed the direction of my life and helped me find my wife, Jessica.

I graduated Cornell University School of Mechanical Engineering in 1992. The economy was bad and my prospects were slim. I managed to get an east coast aerospace job right after graduation, but from 1992 to 1995 the company was sold once and then merged. I worked for three different companies while sitting at the same desk over three years. I opted to leave aerospace and the east coast. I moved to California to do something very irresponsible.

"I moved to California to do something very irresponsible."

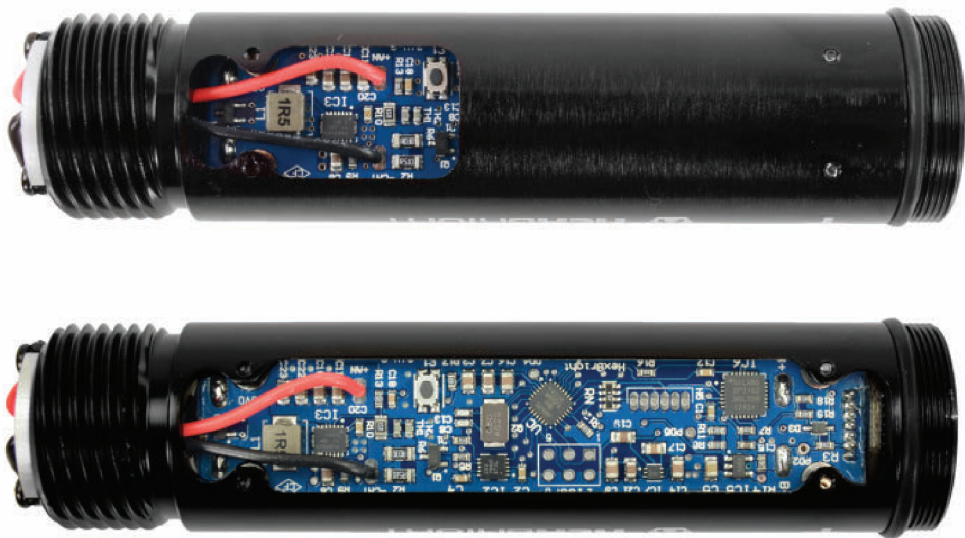
I moved to North Hollywood when I was 25 to follow my teenage dream of working in the movies; specifically in a field called "practical effects." Practical effects are all those mechanical and puppet effects that are filmed live in front of a camera — not created and added digitally. They are typically spacecraft and miniature models, monster costumes, and animatronic puppets. They might be touched up digitally during post-production, but the original seed is based on physical props.

During this time, I really learned how to design and fabricate mechanical devices. It was a non-stop grind as I worked on sci-fi movies like *Starship Troopers*, *Virus*, and *Species*, as well as television shows such as *Star Trek Voyager*. It was also the beginning of my education in robot design.

During my late twenties, I discovered the San Francisco based event called 'Robot Wars' and started building my idea of the ultimate robot warrior: an eight legged 120 lb walking machine with an array of Sears Craftsman circular saw blades

on both ends. The legs were powered by wheelchair motors and the saw blades were belt linked to dual weed whacker two-stroke engines. I won many fights, and was written up in several trade magazines for making a very successful walking machine. One of those magazines was *Nuts & Volts*.

Looking back, that first article written by Dan Danknick would be a critical point during my life. It was read by an engineering VP at Walt Disney Imagineering. A call was made, an interview date set, and I was soon working for "the Mouse" doing Show-Ride Engineering. Show-Ride Engineering was essentially working out the problems of making theme-rides last for decades. I went from movie making to roller coaster design, and the timing was better than I could have realized. During the early 2000s, computer digital effects started to take over the movie industry and the practical effects industry dwindled away. More importantly, it was at Walt Disney I met and started dating my future wife, Jessica.



While I was working at Walt Disney, two ambitious Robot Wars veterans struck a deal with Comedy Central to put robot fighting on television. This is how the TV show of BattleBots started. Between work and dating my girlfriend, I built robots for the show.

The TV series gained popularity, and next thing I knew I was quitting my job with Walt Disney (no way I was going to quit dating Jessica) and building robots full time for BattleBots. The "hobby" I was passionate about suddenly became my day job. I built up a team of five people, all of whom I am still good friends with to this day.

This television exposure led to other bits on The Tonight Show with Jay Leno and The Today Show with Matt Lauer. When the TV show was cancelled, I was invited to work with a bunch of ex-Disney R&D folks at a very creative Los Angeles based company called Applied Minds. I took my teammates with me, and we all said farewell to BattleBots and started a new chapter. I worked at Applied Minds for five years when

my wife and I decided to move the kids out of the LA area.

I have had a variety of jobs working for both commercial and military projects, but my early days of small shops and fast paced projects really shaped everything I did and how I tackled problems. I wasn't afraid to try something new and make the unavoidable mistakes of doing something for the first time. I realized something critical in my early days: If you do something truly unique, half the world will write about it and the other half will offer you a job.

## HexBright FLEX – My Runaway Kickstarter Project

Today, Kickstarter is a well-known name, but it was a relatively new concept when I first heard of it two years ago. I was intrigued by the idea of crowd-funding projects. At the time, I was designing lights for a bike accessory company and was interested in making my own hand

light with only the functions I wanted (I have no need for strobes or Morse code for my personal flashlights). Just like 15 years prior when I started making fighting robots for Robot Wars and BattleBots, I decided to just go for it and launched my HexBright FLEX flashlight project on Kickstarter. I figured if I wanted my own programmable flashlight, others might want one too.

My video was rough and my idea was simple: a high powered 500 lumen USB rechargeable flashlight you can program like you would an Arduino device. You can find my original video at [www.kickstarter.com/projects/527051507/hexbright-an-open-source-light?ref=live](http://www.kickstarter.com/projects/527051507/hexbright-an-open-source-light?ref=live).

Apparently, there were a lot of people who also wanted their own programmable torch. After about 60 days, I raised just over \$250K in funding — making it one of the top 10 most funded Kickstarter projects at that time. Considering my original goal was to raise \$31K, you might think I was ecstatic about raising \$250K. However, I seriously considered cancelling the project

right before the funding period was over. Yep. I almost cancelled my Kickstarter project with a quarter of a million dollars on the line.

## "I was very close to cancelling my Kickstarter project with a quarter of a million dollars on the line."

Let me explain a few details about Kickstarter in case you're not familiar. You set a target goal for raising money (in my case, it was \$31K based on making about 500 lights). You offer rewards, and people pledge you money by leaving their credit card information with the Amazon payment system through the Kickstarter website. Credit card accounts are not actually charged until after the funding period if you meet your goal. Once the funding period is over, Kickstarter (via Amazon payments) starts charging all those credit card accounts and collects pledge money.

It's a brilliant system because if you do not get enough pledges by the end of the funding period, nothing happens. No credit cards get charged. So, to recap, after 60 days if I only raised \$30,999 pledges of my \$31,000 target goal my project would have been labeled "FAIL!" and none of the \$30,999 would ever be collected. You also have the option to cancel your project any time before the funding period is over, regardless of whether you hit your goal or not.

However, once the funding period is over, you are very much committed to the project and if your project is huge, you are locked into a major financial commitment.

Kickstarter and Amazon take about 10% of the crowd funding, leaving the project creator 90% to undertake his/her proposal. This 10% fee happens right after the funding period expires. Kickstarter/Amazon charge all your backers (using their

credit card accounts) and move that pledge money into your bank account, taking their cut in the process. After that transaction is complete, both Kickstarter and Amazon are finished. It is up to the project creator to produce the rewards, and it is up to the crowd to police you.

Kickstarter's official line is that the project creator can either send rewards or return money back to the crowd, but that does not include the 10% fee Kickstarter/Amazon took. So, to sum up, if you successfully raise \$1,000 on Kickstarter, you collect \$900 to do the project after fees. If you can't finish the project, you can give \$1,000 back to the crowd, but you are out \$100 of your own money.

However, I raised \$250K in pledges and was risking \$25K of my own money. Plus, instead of 500 flashlights I had to make closer to 5,000 – ten times more work than I originally anticipated. With one day left for my funding period, I had to decide whether to hit the big red cancel button before money exchanged hands or go for it.

Well, okay, in the end I believed I could pull it off. It would be tough because I made some initial critical mistakes. There were three major blunders I made right off the bat:

First, I offered the project for too low a value. In retrospect, it should have been a \$75 reward. The 10% Kickstarter fees don't seem too bad, but they are still significant. Also, when a project explodes way past your target, you suddenly need a lot more help and you don't have the resources to buy that help if your price point is too low.

The last kick in the wallet were double shipping costs. I budgeted shipping costs to my Kickstarter backers, but in reality you actually pay for shipping twice. First, I had to pay for parts to come to me, then paid for assembled HexBright FLEX units to go to backers. This killed what little buffer I had. Kickstarter recommends that you offer rewards for a good value, but you also have to make sure you can cover a fair amount of mistakes.

My second initial mistake was offering multiple units at a discount and too much variety. A single HexBright pledge was \$60 but I offered two HexBright lights for \$110, saving \$10. I didn't consider that people would find a friend so they could each save \$5. Half of all my Kickstarter backers pledged for two or more HexBright FLEX lights, driving my budget per light down 10%. I also offered personalized engravings for extra pledge money. This offer actually increased my funds more than the cost, but it was an additional logistic hassle on an already massive project.

Third, I did not have the HexBright design completely 100% baked. I had the rough physical working prototype and the mechanical design fleshed out, but I did not have my electronics completed. This last issue was the most difficult hurdle to get over during my project.

*(Kickstarter changed some of their requirements since I started my project. Specifically for technology projects like my own, you can no longer offer multiple rewards at a discount, and you must have a 100% working prototype and offer no new features – what you see is what you get. In retrospect, I completely agree with Kickstarter's policy changes.)*

## Good, Fast, Cheap – Pick Any Two

The funding period was over and it was time to start building the HexBright. During the Kickstarter pledge period, I had requirements defined. I wanted it to have a USB interface for both programming and recharging, and I wanted the USB plug behind a sealed O-ring. A lot of the design came out of these requirements. I also wanted to make it out of one-piece aluminum hex stock to give it a unique look and feel. The only major mechanical refinement I made along the way was changing the front reflector dish to a TIR (total internal reflection) lens.

During this design process, I met a variety of people. I met an optics

expert from Russia who helped me with my new TIR lens design. A South African graphics designer came up with the HexBright logo and battery wrap design.

A heat transfer expert from Norway was happy to look over my design and do some analysis. There was also an electrical engineer from Colorado that would later become critical for finishing the project.

A big struggle (again) was the

electronics. The working mechanical design was figured out, but the electronics issue was delaying the entire project for months. I could not start production of any parts until I knew the electronics worked.

Although it was hard on my original electrical engineer, I had to get more electrical engineers involved. I found two EEs working in LED technology to finish and test the FLEX design, and I contacted two other EE friends of

mine to do component board layout.

After assembling a more complete team, we had a working board in about six weeks and went into initial production. My project was late, but it was still under budget and going to be an excellent creation. As the saying goes, good, fast, or cheap — pick any two.

## Dealing With Large Crowds

Crowd-funded projects are not just about managing a project. It is about managing the crowd too. I was getting a lot of feedback and requests from my 3,000+ backers. Many requests I had to politely ignore, but others were good. There were some requests to add an accelerometer to the board. This last was a great idea and although it added more cost, I had to pursue it. There were plenty of "cool idea!" and "can't wait!" emails to go through, as well as open forum comments back and forth between backers. It was a very interesting and fun (at times) process.

Crowd correspondence can cut both ways — you are basically babysitting a bunch of people eager to hear about progress and when they will get their reward. You have to keep in constant communication and try to assure the more skeptical and less patient people things are progressing. Running a very large Kickstarter project can be a lot like driving with impatient kids — you constantly get asked if you are "there yet." Answering emails was really a full time job in itself.

Running a very large Kickstarter project can be a lot like driving with impatient kids — you constantly get asked if you are "there yet."



"I started thinking about other ways to apply Loctite. I couldn't help myself, and developed an entirely new product called "Drip-Well."

All comments on Kickstarter are public domain and you have NO control over them. Once they are up (including your own), you can never change them. At first, I tried to be thorough in my responses to the public questions in the comments section but became concerned that someone might take one item out of my response and misconstrue what I was saying.

It got difficult about six months after the project funded because I had not delivered yet. I was struggling with electronics and I had to spend a lot of time answering questions. I simply could not risk going into production on any physical hardware until the electronics were complete. A \$10 mistake in scrapped parts would cost \$50,000. I was EXTREMELY cautious and it took a long time to get it right.

Even after finishing the mechanical and electrical design, there were still hiccups in production. My first batch of TIR lens was bad and had to be scrapped. That hurt. I started assembling units with O-rings that were a little too big. I also made enhancements along the way, constantly improving both the electronics and physical body.

I had parts in the field start to

"Within two days, I had over 150 positive HexBright FLEX reviews on Amazon."

unscrew and I had to start using Loctite in my HexBright FLEX assembly process. I looked at professional equipment for applying Loctite in an assembly line and quickly realized it was way too expensive for me. I started thinking about other ways to apply Loctite. I couldn't help myself, and developed an entirely new product called "Drip-Well." Drip-Well is a very simple method for home garage builders like myself to use and store Loctite.

In the end, I started shipping finished HexBright FLEXs about a year and four months after my project was funded. To be blunt, this was the result of my making mistakes about initial costs, not 100% working out my designs, and not making tough decisions earlier. I'm not ashamed or embarrassed by these mistakes. I consider this the natural process of doing anything new and sure signs of gaining experience. Also, I cannot express the feeling I had as my backers received their HexBright FLEX torches and started emailing me to say "Wow! Worth the wait!" and "Great job!"

## After Kickstarter

I realized early on, I would have to sell an extra 500 units past Kickstarter to break even (not counting my time). I set up a storefront at [www.hexbright.com](http://www.hexbright.com) but quickly realized that was not enough. I decided to try selling on Amazon, and asked my Kickstarter backers if they would write a review about their HexBright FLEX. Within two days, I had over 150 positive HexBright FLEX reviews on Amazon. I was blown away by all the stories and great reviews people posted.

Later, I realized this was not just because I made a great light. It was also because I stayed in communication with my backers. They followed my process and journey, and were happy to continue to help by posting good reviews.

Right now, I am still selling units on Amazon and still making small improvements as I go. I will probably start a new project soon but I'm not sure what it will be yet. **NV**



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# MakerPlot <sup>Part 3</sup>

## The DIY Software Kit

By John Gavlik and  
Martin Hebel

Post comments on this article and find any associated files  
and/or downloads at [www.nutsvolts.com/  
index.php7/magazine/article/december2013\\_MakerPlot](http://www.nutsvolts.com/index.php7/magazine/article/december2013_MakerPlot).

In this article, we'll show you how to connect your micro to MakerPlot in order to plot a single channel of analog data. Plus, we'll show you how you can scale the raw analog-to-digital converter (ADC) data into corresponding voltage levels. This means you don't have to do any math inside your micro's code; MakerPlot handles everything for you. Let's get going.

### Preparing Our Uno and PC

For this and subsequent articles, we're going to use an Arduino Uno as the reference microcontroller. To make things more interesting, we're going to add a 10K potentiometer wiper pin to the A0 analog input pin and connect the other two pins to +5 volts and ground on the Uno. This will demonstrate how a varying voltage level from the pot gets translated into an A2D (analog to digital) value for our analog scaling example. **Figure 1** illustrates the 10K pot hookup.

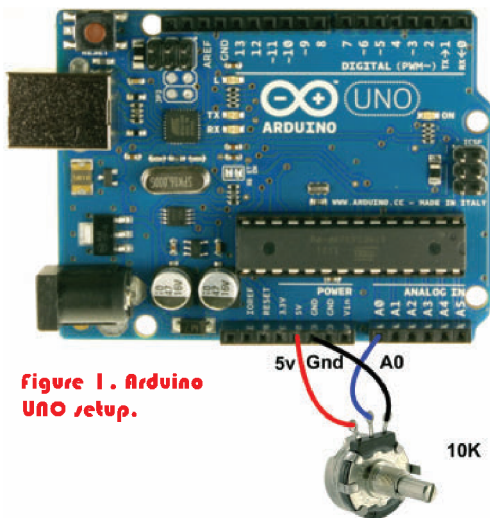
We're using the Uno because it comes complete with an FTDI serial-to-USB chip, along with a standard USB-B connector that makes it easy to create a serial connection to a PC using a standard A-B USB cable. Of course, you can use any micro you have that can output serial A2D data like the PICAXE, Raspberry Pi, or even one of the kits you may have built from a *Nuts & Volts* article.

Since we're using a USB connection, you'll also need to install a suitable USB driver on the PC side. For the FTDI chip, this is easily done by going to their website at [www.ftdichip.com/Drivers/VCP.htm](http://www.ftdichip.com/Drivers/VCP.htm) and selecting the proper driver. Make sure that the USB driver is installed before going any further or else things will probably not work unless your PC already has the driver installed.

### Creating a Sketch

Next comes creating a simple Arduino sketch to configure and send the potentiometer's A2D data from the Uno to the PC. **Figure 2** shows the sketch code listing. It begins by defining a variable called **AnalogInPin** that represents the A0 pin and configures the comm port with the Arduino's **Serial.Begin(9600)** instruction. For the Loop, it reads the A2D value at A0 and does a **Serial.Println** that outputs the ASCII value of the reading via the serial port. Note that the **Serial.Println** instruction also appends a carriage return after the ASCII A2D value which tells MakerPlot that this is the end of the data string for this data set. Finally, we delay 100 milliseconds and repeat.

Be sure to first verify then compile the sketch, then upload it to your Uno and check it against the Arduino



**Figure 1. Arduino  
Uno setup.**

```

File Edit Sketch Tools Help
sketch_jul06a.g

// Connecting To MakerPlot
// This sketch is in the public domain

const int analogInPin = A0; // Analog input pin that the potentiometer is attached to
int sensorValue = 0; // value read from the pot

void setup() {
  // configure hardware
  // initialize serial communications at 9600 bps:
  Serial.begin(9600);
}

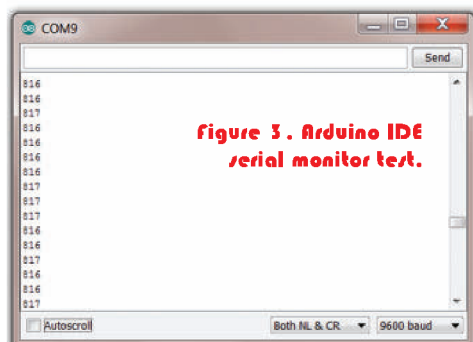
void loop() {
  // read the analog in value:
  sensorValue = analogRead(analogInPin);

  // print the analog values formatted for MakerPlot
  Serial.println(sensorValue); // send analog value

  // wait 100 milliseconds before the next loop
  delay(100);
}

```

**Figure 2.**  
**Arduino sketch**  
**for connecting**  
**to MakerPlot.**



**Figure 3. Arduino IDE**  
**serial monitor test.**

IDE **Serial Monitor** program (**Figure 3**) to make sure it all works. Adjust the pot shaft to create different values that should range from 0 to 1023. If that all works properly, then you're ready to connect to MakerPlot.

Before you go any further, however, close the Arduino **Serial Monitor** program. This will free up the comm port for MakerPlot. Also, make sure that the virtual comm port number assigned to the Uno is 15 or lower; currently, MakerPlot has a problem with comm ports greater than 15. This will be corrected in a future release.

## Installing and Connecting to MakerPlot

If you haven't already done so, go to [www.makerplot.com](http://www.makerplot.com) and click on the **Free Trial Download** menu link to download MakerPlot as a 30 day free trial and install it on your PC. The trial version is exactly like the commercial version except that your comm port connection times out after three minutes. Then, you'll need to reconnect for another three minute session. Otherwise, the trial version is the same as the commercial version. Follow the instructions for installing MakerPlot and you'll be ready to go to the next step.

**Figure 4** shows the Desktop icon that appears after the installation is complete. Click on the Desktop icon and the **Sign On Interface** will appear (**Figure 5**). Click on the **Run Standard**



**Figure 4.**  
**MakerPlot**  
**desktop**  
**icon.**

**Interface** button (middle left) to bring it up (**Figure 6**). Verify that the **Control** menu panel looks something like **Figure 7**. Our port number is 9. While yours may be different, it shouldn't be over 15. If it is, go to the Windows Device Manager → Ports (Com & Lpt) → Arduino Uno R3 (comm port) and change it to a lower number.

## Plotting Data

If the above looks good, then click the red rocker switch in the **Control** menu. It will change from red to green; you should see a black horizontal line being plotted across the **Standard Interface** screen. Adjust the pot shaft and the plot should begin to move up and down correspondingly (**Figure 8**).



**Figure 5. MakerPlot sign on interface.**

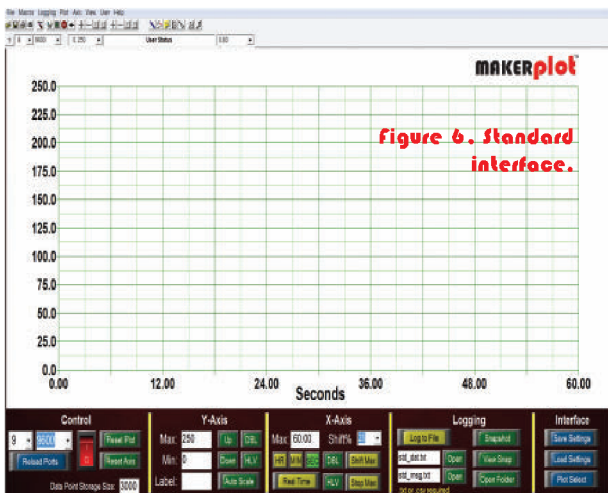


Figure 6. Standard interface.

You will also need to adjust MakerPlot's vertical scale to a different value to see the entire plot. This is done by clicking the **DBL** button under the **Y-Axis** menu (Figure 9) a couple of times until it gets to 1000, which is just below the pot's maximum value of 1023; the Atmel 328P micro in the Uno has a 10-bit ADC, so the raw values range from 0 to 1023.

If you want, you can fine-tune the Y axis setting by

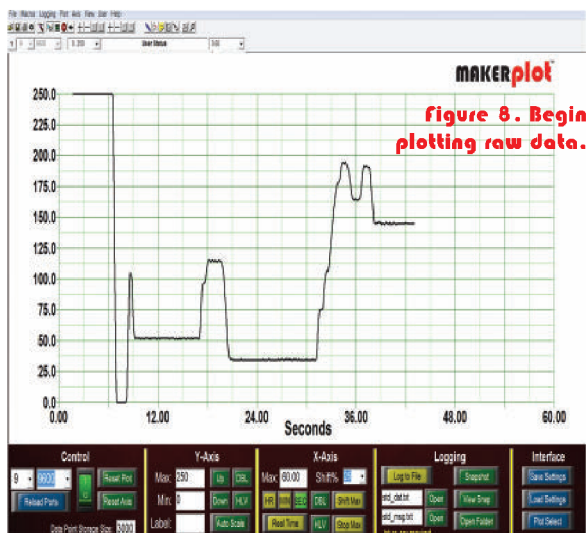


Figure 8. Begin plotting raw data.

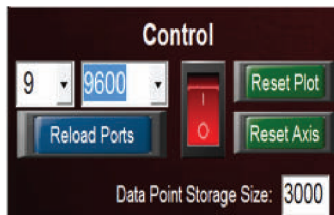


Figure 7. Control menu panel.

keying in 1050 in the MAX box. Just make sure to depress the Enter key after you put in this value. Now, the Y axis goes from 0 to 1050, and you can see all of the pot values going from 0 to 1023 (Figure 10).

## Scaling the Analog Data

Up until now, we have been plotting the raw 10-bit A2D value that's generated by varying the potentiometer shaft. Since our pot is connected between five volts and ground, the actual voltage that's going into the A2D pin (A0) is what we really want to be plotting. There are two ways to do this. One way is to code the math in the sketch and output the result via the serial link as a series of ASCII characters, or let MakerPlot do it. For this example, we'll defer to the latter since it will be easier and will also show you a neat MakerPlot feature.

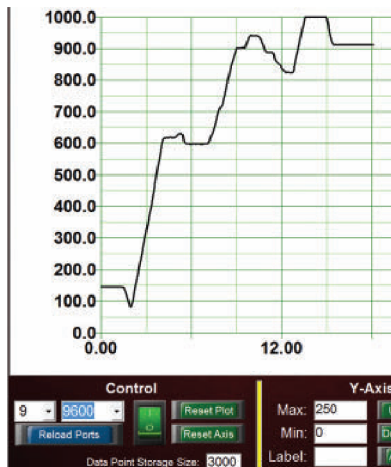
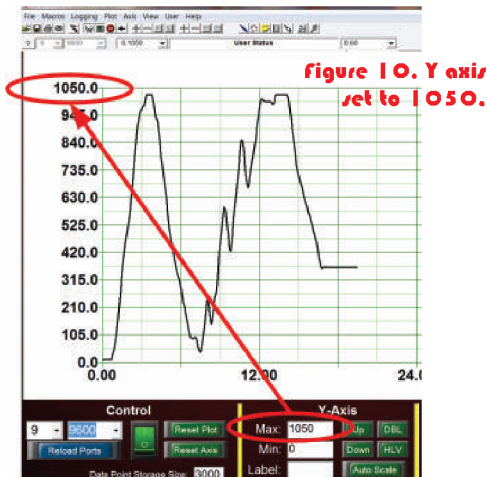
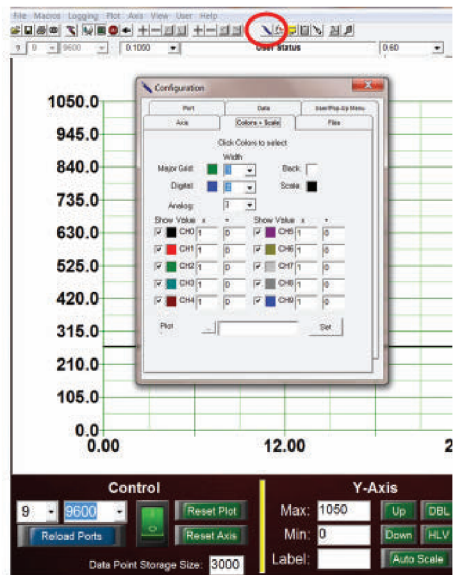


Figure 9. Increase Y axis to 1000.

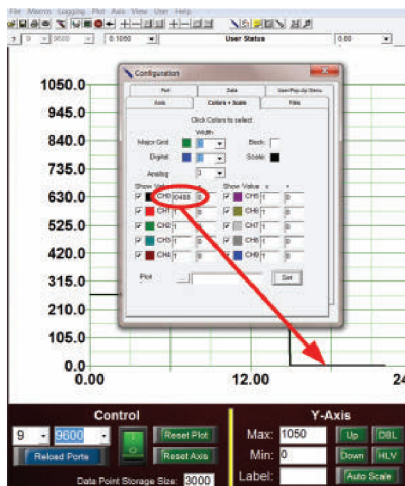


To scale the raw incoming A2D data, click on the pencil icon to bring up the **Configuration** menu (Figure 11). Next, click on the **Colors + Scales** tab. You will notice that the lower part of the tab has settings for all 10 of the analog channels (0 through 9). Notice that each analog channel has a different assigned color that you can change if you wish; each analog channel is selected (or deselected) with a check mark in the box to the left.

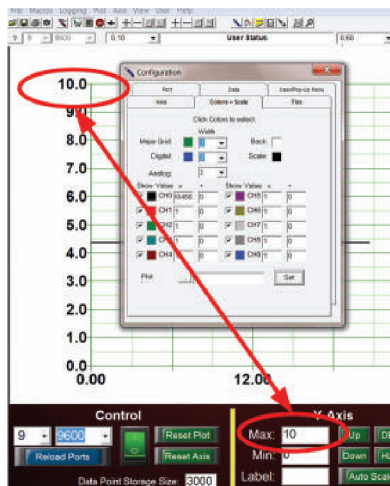


**figure 11. Configuration menu.**

However, since we're plotting only one channel of analog data (channel 0 by default), the color is black. We can leave the other analog channels checked since there is

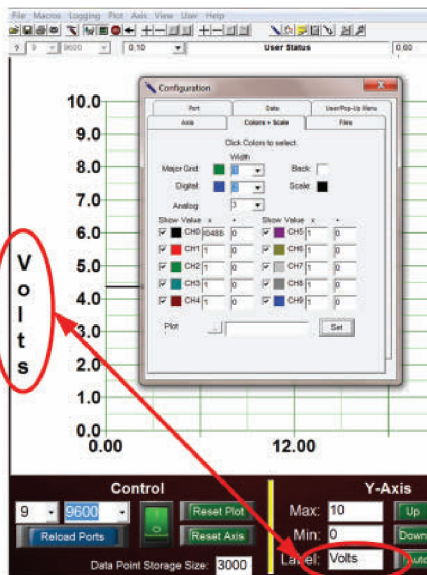


**figure 12. Scale to voltage.**

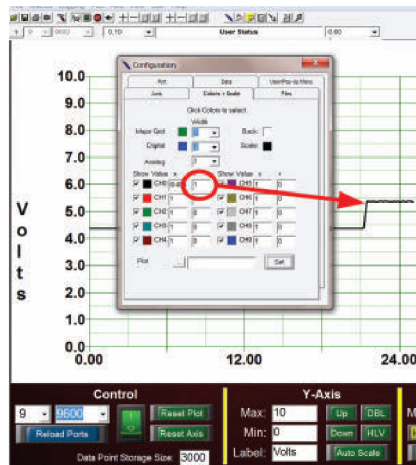


**figure 13. Scale to voltage.**





**figure 1 4. label Y-axis.**



**figure 1 5. Add positive bias.**

only one analog channel coming into MakerPlot.

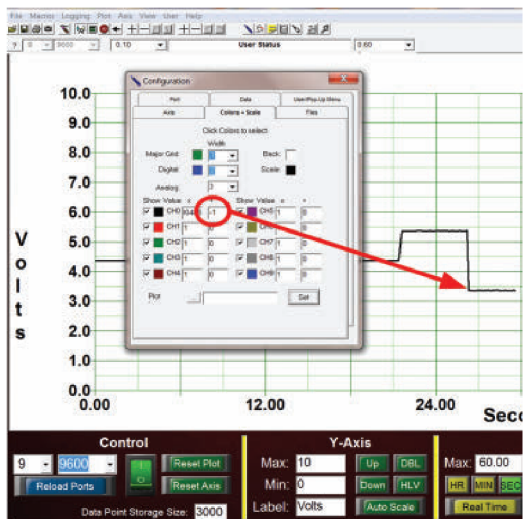
What's important to note are the text boxes to the right of the color squares. These are what we need to change in order to scale the analog data to make it conform to the actual voltage level that the micro sees at the A0 pin. The first text box (the one that has a 1 in it now) is the multiplier adjustment value. Right now, it's set to 1 meaning that whatever analog value comes into MakerPlot on channel 0, that's what will be plotted, i.e., the analog value times one (x1). This holds true since our analog value range is 0 to 1023 at the moment — which is what we're seeing on the plot.

## Doing the Math

The value in the first text box needs to be changed to a decimal fraction to represent the true potentiometer voltage value. Here's the equation to determine this fractional value:

$$X = 5.00 \text{ volts} / 1024 \text{ steps} \\ = 0.00488 \text{ volts} / \text{step}$$

This means that each step of the A2D converter is worth 0.00488 volts. So, click on the first text box and key in 0.00488; make sure to push the Enter key (Figure 12). Now look at the plot; it's nearly at the bottom of the plot area. This is to be expected, since now we need



**figure 1 6. Add negative bias.**



to adjust our large Y axis vertical scale to match the new lower voltage range.

## Readjusting and Labeling the Y Axis

The easy way to adjust the Y axis is to click the **HLV** button in the **Y-Axis** menu; this just gets the plot in the general range of its new zero to five volt range. A better way is to key in the value "10" in the **MAX** text box (**Figure 13**). You'll see that the new value of 10 represents a Y axis value of zero to 10 volts. Plus, you can click the **HLV** or **DBL** buttons to automatically adjust the voltage scale up or down by half or double, respectively.

We're still not done. What remains is to label the Y axis properly — in this case, to "Volts." To do this, simply key in the word Volts in the **Label** text box and hit the Enter key (**Figure 14**). Now, the Y scale represents the voltage produced by the potentiometer.

## Adding Bias to the Plot

One final thing before we conclude on this topic is how to use the bias setting text box. Right now, it has the value 0 in it.

Since we've adjusted our multiplier value, our analog data (correctly) goes from zero volts minimum to +5 volts maximum. However, we can add a bias — either positive or negative — to this range by keying it into the text box just to the right of the previous text box where we keyed in our 0.00488 value. The bias text box has a + label at the top, but the value you key in can be either a positive or negative value; it can be a whole, fractional, or combination whole-fractional value.

We've keyed in a value of 1 (positive) into the bias text box to illustrate what happens to the plot

(**Figure 15**). Notice the plot jumps up one volt from where it was originally. Now, we'll key in a negative value of minus one (-1) and notice the plot falls one volt from the actual A2D voltage value (**Figure 16**). Finally, we key in a 0 just to get things back to normal.

Having the ability to set a bias level for your analog data has many advantages, since you may want to represent negative voltage data that can't conveniently be done with a standard A2D setup. Once again, you can key in both whole numbers and decimal fractions — not just whole numbers.

## Conclusion

What you've learned in this article is how to connect to MakerPlot and how it can be configured to plot one channel of analog data from your micro. We also showed you how to correctly scale and bias your analog data to represent the voltage going into the micro's A2D converter. To help you further understand what's happening, there are several videos on these subjects on the MakerPlot website at [www.makerplot.com](http://www.makerplot.com). Just click on the **Basic Plotting** and **Learn** video menu links and you'll be treated to video examples of these subjects and a lot more.

In the next article, we'll expand on our Uno setup to show you how you can play back the data generated by the potentiometer adjustments and how to data log all of it to an Excel® file. We'll show you how to add digital signals to the mix, as well.

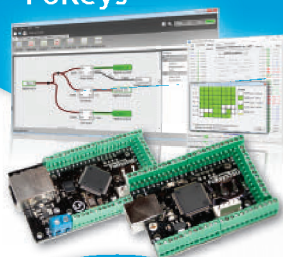
Remember, MakerPlot is available as a free 30-day trial download from [www.makerplot.com](http://www.makerplot.com). If you like what you see and what it does, you can order it from the NV Webstore at a discounted price.

That's all for now, so just remember: **Got Data – MakerPlot It!**  
**NV**

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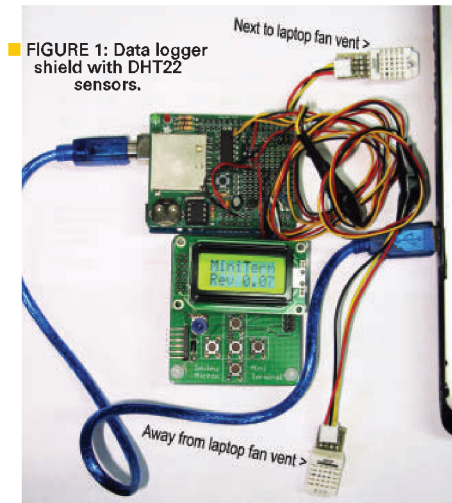


# Arduino Handheld Prototyper

## Part 6

# Data Logging

Over the past several months, we have been learning to use the Arduino handheld prototyper (AHP) — a device that lets us design prototypes on a breadboard with the Arduino proto shield and communicate with the PC mini terminal. Of course, this is all tied together with a plastic base so that you can carry the entire development system around in your hand (Figure 1).



■ FIGURE 1: Data logger shield with DHT22 sensors.

Last month, we began learning how to record sensor data by seeing how much data we could reasonably save on an Arduino using its resident memory. We finished with a link to a test program (*fac\_data\_logger*) that let us try out the concepts.

So, what if we want to log a lot of data? We really have two choices. First, we can keep the data logger tethered to a PC and use the serial port to upload the data as it comes in. This is great for applications where you don't mind having a PC handy, but what about the 'handheld' part of our prototyper? How can we collect lots of data and have the AHP embedded far away from a PC?

One good solution is to use an SD card since you can store a bazillion samples and then take the SD card out of the AHP and plug it into the card slot on a PC to read the data. Or, you can leave it in the AHP and upload the data to the PC via the serial port. Either way, once the data is on the PC we can put it in a spreadsheet and generate charts.

Let's look first at how to upload the sensor data directly to the PC via the serial port, then we'll look at using the SD card — moving it between the AHP and PC.

## Logging Data to a Spreadsheet Chart

Let's simplify things by separating the process of getting the sensor data from the process of uploading data for use in a spreadsheet chart. Let's generate a test set of data (four sine waves on the Arduino), upload it using PuTTY, then finally chart it with LibreOffice Calc.

### Create Some Sine Wave Data in the Arduino

I've written a small program that generates data for four sine waves and stores this data into a two-dimensional array, then it sends this data to the PC (*sd\_sine\_array\_test.ino*). The data is in CSV format. Traditionally, CSV means Comma Separated Variable. However, it is actually used as a character separated variable, where the comma character is the most commonly used character.

I assume you are already familiar with spreadsheets and can use either Excel or LibreOffice Calc (which I will use since it is free). In a spreadsheet, the data is arrayed in cells that have numbers assigned to rows and letters assigned to columns. The spreadsheet knows what a text file with the suffix .csv is and looks for two special characters: the comma to separate columns and the line feed to separate rows. I'm going to also assume you know how the *sin()* function works in the Arduino, and I'll use it to generate the four data sets with each sine wave offset by 45 degrees from the other waves.

The following Arduino listing for the *setup()* function will generate the data for us and will send it to the PC as a .csv file:

```
void setup()
{
  Serial.begin(57600);

  float in, out;
  uint8_t data[4][62];
  uint8_t count = 0;
  uint8_t i;

  for (in = 0; in <= 6.283; in = in + 0.1)
  {
    out = sin(in) * 127.5 + 127.5;
    data[0][count] = out;
    out = sin(in+1.570) * 127.5 - 127.5;
    data[1][count] = out;
    out = sin(in+3.142) * 127.5 - 127.5;
    data[2][count] = out;
    out = sin(in+4.712) * 127.5 - 127.5;
    data[3][count] = out;

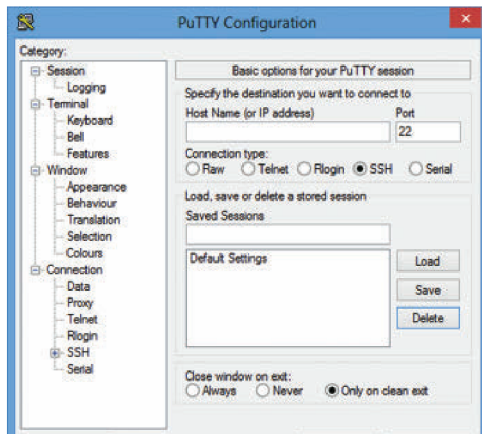
    for(i = 0; i < count-1; i++)
    {
      Serial.print(data[0][i]);
      Serial.print(",");
      Serial.print(data[1][i]);
      Serial.print(",");
      Serial.print(data[2][i]);
      Serial.print(",");
      Serial.println(data[3][i]);
    }
  }

  void loop()
  {
    // do nothing
  }
}
```

You can purchase the Arduino Proto Shield Kit, the I<sup>2</sup>C Mini Terminal Kit, or both of them in the Arduino Handheld Prototyper Kit from the *Nuts & Volts* webstore.



■ FIGURE 2: PuTTY desktop icon.



■ FIGURE 3: PuTTY open window.

This will send the csv data out the serial port where it can be collected into a .csv file on the PC. Now that we can generate some fake data, let's see how to upload it to a PC and then use it to draw a chart.

### Using PuTTY to Upload the Data

In previous articles, I discussed how to write serial terminal programs using Visual C# or Visual Basic .NET. A data logger would certainly be a good application for these programs, but for those not already familiar with these languages, the learning process isn't really related to the actual process of logging data from an Arduino to a PC.

So, let's use an already written and tested terminal program to log the data from the Arduino: PuTTY.

We will then use a spreadsheet program to take that data log and draw a chart of the data that will make it much easier to see what the data is trying to tell us. You can download PuTTY from [www.chiark.greenend.org.uk/~sgtatham/putty/download.html](http://www.chiark.greenend.org.uk/~sgtatham/putty/download.html).

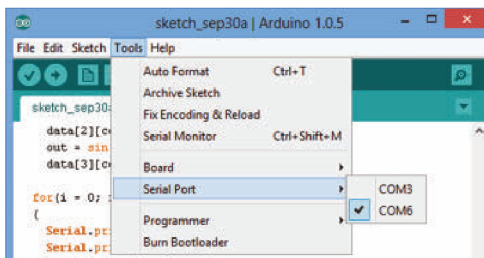
PuTTY is designed to be a general-purpose program that lets folks use a multi-user computer from a remote location, and thus has a LOT of features — most of which we have no use for. The trick is finding just those features that let us log our Arduino data to the PC. Let's do that cookbook style.

Download PuTTY and put it on your desktop (Figure 2). Open PuTTY as shown in Figure 3.

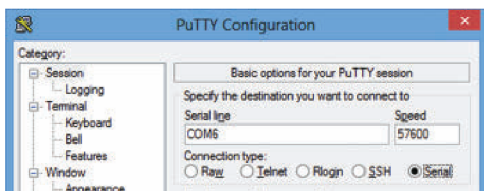
Click on the 'Connection type:' radio button for serial, then enter the COM# for your Arduino. You can find this number by opening the Arduino menu Tools/Serial Port as shown in Figure 4. Enter this COM# in the Serial line text box and enter the baud rate in the Speed box as shown in

**Figure 5.** Next, click on the Terminal Category and in the 'Line discipline options,' click the 'Force on' radio buttons for both 'Local echo' and 'Local line editing' as shown in Figure 6.

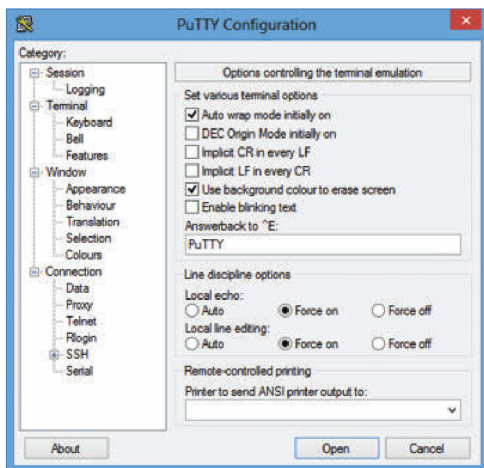
Next, we want to create a file to save our logged data. Open the Session Logging window and click the 'Printable output' radio item. We will create a file name of



■ FIGURE 4: Arduino serial port.



■ FIGURE 5: PuTTY serial line.

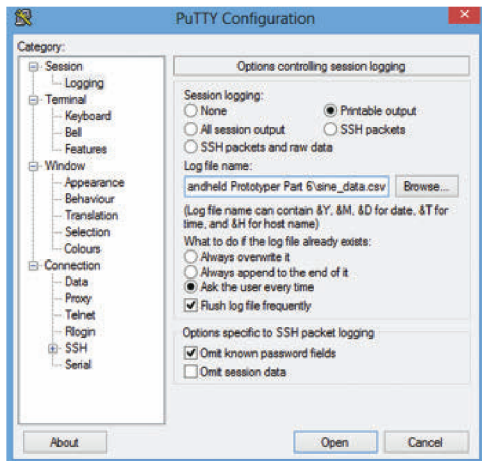


■ FIGURE 6: PuTTY terminal options.

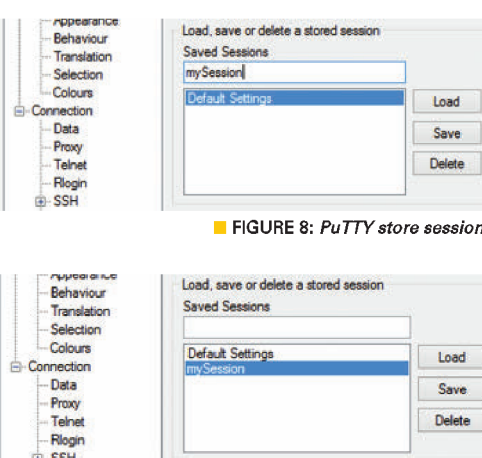
*sine\_data.csv* (more on the name in a moment) by clicking the browse button, then navigating to the directory we want to use. Enter the file name as shown in Figure 7.

We can now use PuTTY, but let's first save all the settings we just input so that we can recall them the next time we want to use this program.

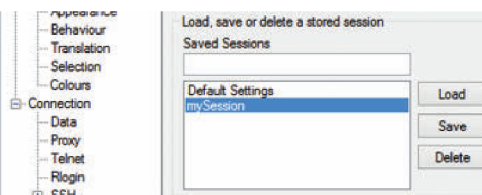
Return to the Category Session and save the session settings by typing in a session name (I'll use mySession) in the 'Saved Sessions' text box as shown in Figure 8



■ FIGURE 7: PuTTY save log file.



■ FIGURE 8: PuTTY store session.



■ FIGURE 9: PuTTY load session.



and click the Save button.

This will store the session as shown in **Figure 9**. The next time you open PuTTY, you'll have the option of clicking on the mySession item and the 'Load' button to have PuTTY install your custom settings. Now, we are ready to use PuTTY to log a session from the Arduino.

### Upload the Arduino Data to PuTTY

Click on the 'Open' window in PuTTY. If you've gotten the Arduino COM number and baud rate correct, you'll see output from the Arduino *sin\_array\_test.ino* program as shown in **Figure 10**. You can see that the data is now arranged in rows and columns — much like you'd see in a spreadsheet. The data is saved to the *sine\_data.csv* file that we will open in a spreadsheet.

### Open the Data in a Spreadsheet

As I stated earlier, I will use LibreOffice Calc (get it at [LibreOffice.org](http://LibreOffice.org)). Open Calc, and in the File menu select Open, then browse to the *sine\_data.csv* file. It will ask you a question about format; just click yes and the data will load as shown in **Figure 11**.

You'll note that row 1 has some junk data that PuTTY put in as the first line to indicate when the data was logged — just delete that entire row. Next, open the Insert menu and click on the Chart item. The Chart wizard will open and you can select the 'Line' chart type: 'lines only.' This will give you the chart shown in **Figure 12**.

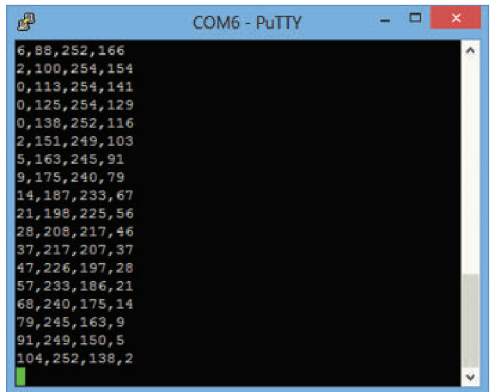
Wow! Would you look at that! Was that easy or what? We have suddenly become kings of data logging and

charting. Now, let's use what we've learned to chart some real data from the AHP fresh air controller.

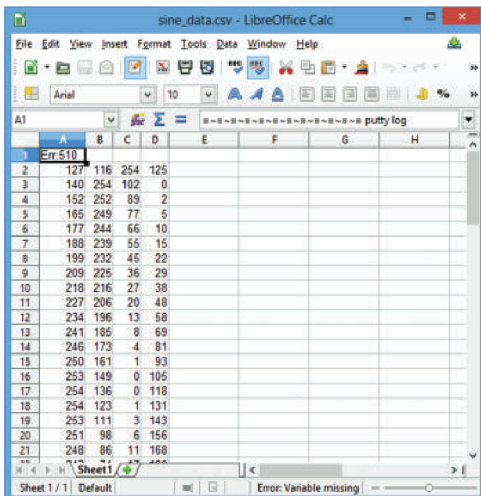
## Logging Data to an SD Card

SD cards can hold some serious data. And when I say serious, I mean SERIOUS. Last month, we learned to collect data using only the resources available on a raw Arduino. We saw how to use some tricks to collect a whopping 3,000 or so samples of data. We figured that was enough to keep track of the fresh air controller for about three days before needing to upload data to the PC.

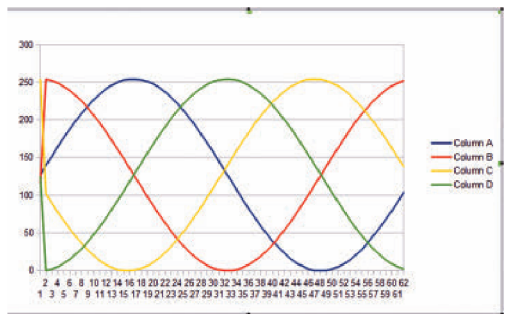
If you use an SD card, you can collect gigabytes of data. **GIGABYTES** — like as in billions and billions and billions as Carl Sagan would say as he gazed his boggled eyes at the stars. I ran a quick and probably inaccurate comparison of using the raw Arduino versus a 2 GB SD card and figure I could save fresh air controller data for



■ FIGURE 10: PuTTY data log.



■ FIGURE 11: Sine wave data in LibreOffice Calc.



■ FIGURE 12: Sine waves in LibreOffice Calc chart.

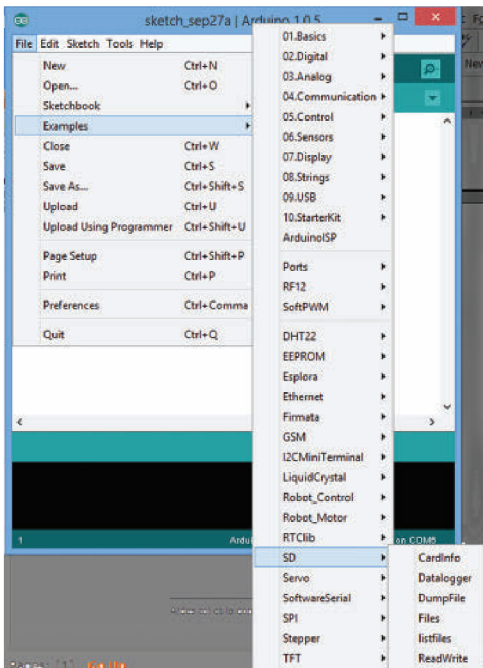
about 80,000 years. (That is just crazy.)

So, why on earth did we go to all that trouble squeezing a measly 3,000-ish samples into the raw Arduino when we can get so much space on a \$5 SD card? Well, part of the reason is cost. Saving the data on the raw Arduino doesn't add any extra expenses, while adding an SD card to an Arduino can cost about \$20 when you include both the card and the required circuitry.

So, only you can decide if your needs warrant that extra expense. To me, it's almost a no-brainer. If you are seriously into data logging, you need the SD card. [Oh, and the other reason for squeezing the data into a raw Arduino is that it was a good learning exercise. Admit it, you did learn some stuff.]

### An Arduino Data Logger Shield

I had an old AdaFruit Arduino data logger shield laying around (refer back to **Figure 1**), so that's what I used with the AHP to develop and test the final software. AdaFruit discontinued that shield in favor of one that comes pre-made with surface-mount parts. That will do just fine, though you do miss the opportunity to inhale some solder fumes.



■ FIGURE 13: Arduino SD card examples.

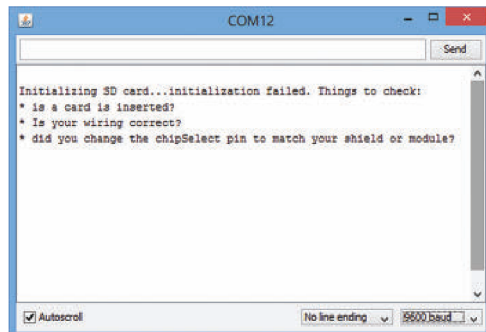
As you can see from the **photo**, I soldered the DHT22 sensors to the prototyping area with the sensors going to pins 8 and 9. Note this change from last month's article. I had used pins 10 and 11, but that conflicts with the signals needed for the SD card. So, I moved them.

### Using an SD Card With the Arduino

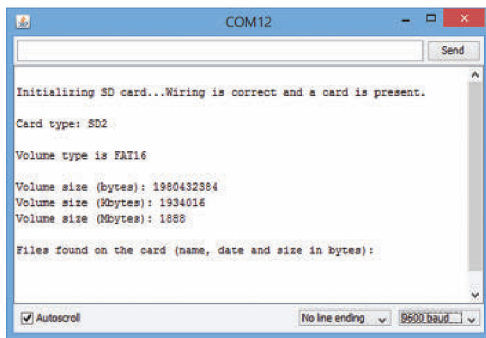
Using the SD card is dead-nuts easy with the Arduino SD library. Just keep in mind that they use 3.3V for both the power and logic interface. They can use about 100 mA at times, and they can be fairly finicky about the logic signals.

Since the Arduino (in general) is 5V, you must have special voltage level-shifter circuits to translate between the two. You could roll your own connections, but there are many shields available with all the current and protection built in. For this article, I used an older data logger shield from AdaFruit.

My shield required that I solder all the through-hole parts on it, but the newer version comes ready to use. The shield has a real time clock built in, so we can get our



■ FIGURE 14: SD Example wrong chipSelect.



■ FIGURE 15: SD example right chipSelect.

*datetime* readings from it as we log our sensor data.

Like many things Arduino, we are blessed to have a library that does what we want to do with an SD card, and we are doubly blessed because the Arduino IDE (Integrated Development Environment) has several very useful examples for using the SD card.

Open the Arduino IDE and then click on the File menu button, then on Examples\SD\ . You'll see the six example files listed in **Figure 13**: CardInfo, DataLogger, DumpFile, Files, listfiles, ReadWrite. These examples will provide the basis for us to build the SD card part of our data logger. You'll want to use the CardInfo example to make sure your SD card setup is working properly. When I first ran the program, I got the information in the Serial Monitor shown in **Figure 14**.

So, I went back and actually looked at the code and saw that the example defaults to the Ethernet shield. If you want to use it with the AdaFruit SD shield, you need to change `chipSelect` from 4 to 10 as follows:

```
//change this to match your SD shield or module;
//Arduino Ethernet shield: pin 4
//Adafruit SD shield and modules: pin 10
//SparkFun SD shield: pin 6
const int chipSelect = 10;
```

**Figure 15** shows the information with the correct `chipSelect` set for a 2 GB card.

### Saving Temperature and Humidity Data in CSV Format

First, we need to decide how we'll save the data so that we can chart it. We will want to have each of the four fresh air controller sensor samples — *inTemp*, *inHum*, *outTemp*, and *outHum* — associated with a *datetime* for each sample interval.

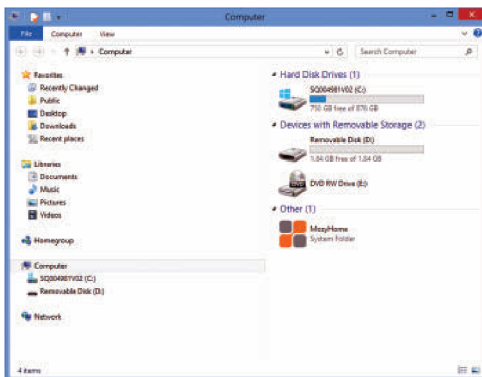
In the last article, we saw that we only need to record

the *datetime* at the beginning of the sampling session, then we can extrapolate the *datetime* for each sample by simply adding the sampling interval. We could still do that, but since we have 2 GB of data to play with, why bother? Let's just get lazy and record the *datetime* for each sample.

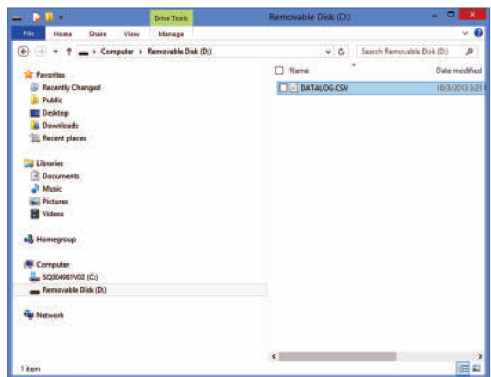
To further simplify things, let's do a test run where we only sample the two DHT22 sensors so that we can show that data and leave the 'Control' part of the fresh air controller software for the moment. We will write a simple program (*sd\_sensor\_test*) that samples the sensors once per five seconds, then saves that data to the SD card. I'll do this sampling next to my laptop, with one sensor hanging out in the room and the other stuck right up next to my laptop's exhaust fan (again, refer to **Figure 1**). Both sensors start at the same temperature and humidity, but the one next to the exhaust sees a rapid increase in temperature and decrease in relative humidity.

We will then upload this data to the PC and chart it as we did with the sine wave data. **Figure 16** shows the results. Since I'm running a bit long on this article, I'll make the source code (*sd\_sensor\_test.ino*) available at the article link. This program loads the data onto the SD card and it also sends it out to the PC at each sample interval. This gives you two ways to get the data.

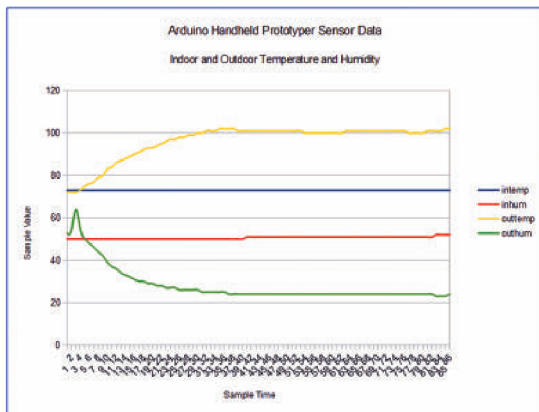
You could get the data using PuTTY as discussed, or you could wait until you've finished sampling and then remove the SD card from the AHP, plug it into the PC, and get the data off the card [we name this file *datalog.csv* in the Arduino source code, and the Arduino creates this file on the SD card]. When you plug the SD card into your PC, it opens the SD card as a 'Device with removable storage' in Windows Explorer. You can access the file just like any other file in a Windows directory as shown in **Figures 16 and 17**.



■ **FIGURE 16: Removable disk D:.**



■ **FIGURE 17: DATALOG.CSV.**



■ FIGURE 18: Sensor data in LibreOffice Calc.

In LibreOffice Calc, I set the chart to only show the data, not the *datetime* since I already know that the data is taken at five second intervals. The *datetime* data is in

*unixtime* which (as we've seen) is the number of seconds since January 1, 1970, and we can take that data and display it anyway we want. This isn't relevant at the moment, so I left it out.

Use the LibreOffice Calc File menu to browse to the *data.log.csv* file, then open it and display the data as you were shown earlier with the sine data as shown in Figure 18.

## Now What?

This is the last of my six part series on the Arduino handheld prototyper. In these articles, we've learned a lot about using the Arduino proto shield and the I<sup>2</sup>C mini terminal combined into the AHP. Now, you can create your own Arduino designs that can be used remotely to talk to someone using a small LCD and five-button navigation system.

You can keep track of the dates and times, and you can store a small amount of data on the Arduino or a large amount of data on an SD card.

Now, go forth and create. **NV**

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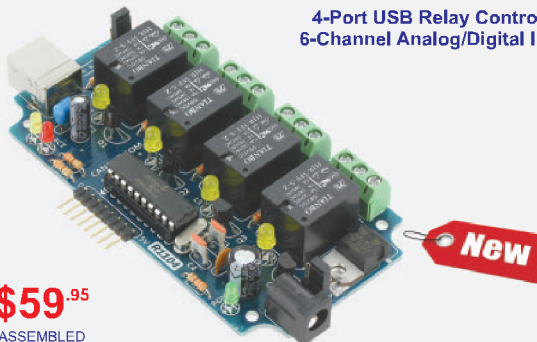


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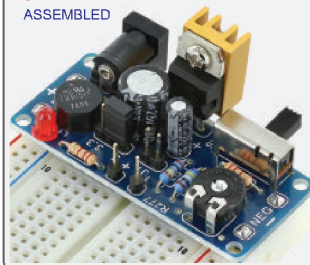
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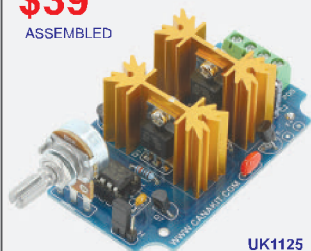
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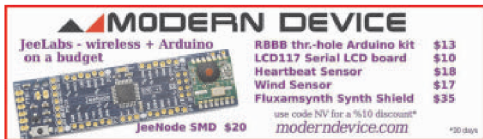
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# Wireless Watches Will Win the Wearable Wars

New class of wearable wireless devices is expected to be popular.

**M**any of you abandoned your wrist watch when you got your cell phone. Cell phones are great watches since the cellular network supplies dead-on accurate time continuously. No need to keep your watch set when the cell phone does it automatically. Now, you could be rethinking the whole watch idea. A new class of wearable wireless devices is now emerging to bring back the watch concept, and with it a whole new world of uses (Figure 1).

## WATCHES: THE TOLERABLE WEARABLES

Watches have always been a status symbol and fashion statement. Think of the Rolex and all its expensive Swiss watch competitors. Then, there are the specialty watches like the Breitling Navigator with its tiny dials and own set of knock-offs. What about that orange-faced Doxa dive watch? And don't forget those popular Mickey Mouse watches that are still around.

My favorite time pieces were an old Casio calculator watch and an "atomic" watch. The Casio had a small but workable keyboard which I used more than I ever thought I would. It also had a stop watch that I used to time my runs. I still have it and it works, but after four broken plastic bands I finally retired it.

My latest watch is the atomic watch that has a built-in radio that

receives the National Institute of Standards and Technology's (NIST) WWVB radio station out of Colorado. It operates at 60 kHz and broadcasts a super accurate time signal. The watch is synced to this time signal, making it about as accurate as the cesium atomic clocks at the station can be. Plus, the watch updates automatically for daylight savings time. I still wear it occasionally but I mostly rely on my cell phone for time.

Watches will always be popular, and the new smartwatches just may create a whole new group of younger wearers who never got into the watch habit. To me, watches are the least offensive of the new wearable computing gadgets. Google's Glass is an example. The small video screen in front of the right eye lets you see any Internet connections and

■ **FIGURE 1.** The watch returns in the form of an electronic peripheral to your smartphone.



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whatever the built-in still and video cameras are looking at. Cyborg creepy doesn't begin to describe it. Yet, I suspect that these glasses will be a popular wearable.

Other wearables you may have seen are the fitness gadgets that measure heart rate, breathing rate, steps taken, and the like. Arm and chest straps with sensors send data to a watch for monitoring.

Even Apple is said to be working on an iWatch, so keep an eye out for it in the coming months.

The new smartwatches are actually peripherals to your smartphone. Think about what your smartphone really is. It is a powerful multi-core computer that happens to have several two-way radios built in for cell phone conversations, email, texts, and Internet access. Your smartphone also runs many different application programs making it as useful as your laptop or PC. Since it is a computer, why not give it some peripherals? For example, a smartphone peripheral is a Bluetooth headset.

The whole idea of a smartwatch is that it is more convenient to use

than your smartphone. You can keep your smartphone in your pocket or purse and rely on the watch for more useful functions. The watch links to the smartphone by way of a Bluetooth radio in both units. You can answer calls, text, take pictures, and, of course, see what time it is. Different watch models have different functions. With a smartwatch, you don't have to be staring down at your phone all the time like most

people do these days.

The best way to describe what these watches do is to introduce you to what is currently available or what will be shortly.

## GALAXY GEAR

The most popular and best selling smartphones in the world are the Galaxy models from Samsung. The Galaxy S3 and S4 models have consistently outsold Apple's iPhones. Their large screen (Figure 2) (5+ inch)

■ **FIGURE 2.** The Samsung Galaxy Note 3 is a popular Android smartphone with LTE 4G service. Its key feature is the amazing 5.7 inch color screen. It has dual front and back cameras, GPS, Wi-Fi, and Bluetooth. Note the stylus for writing and drawing.



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■ **FIGURE 3.** The Galaxy Gear watch works with the Note 3. It tells time, makes and receives calls, and notifies you of texts and emails. Note the camera lens in the band.



Note models seem too big, but have become very popular. Now, Samsung has announced their Galaxy Gear line — a smartwatch that is an accessory to the popular Note 3 model (see **Figure 3**).

The watch has a 1.63 inch AMOLED color touch screen. It has its own 800 MHz processor and lots of RAM. There's a built-in camera for both still pictures and video. Also included are two noise-cancelling microphones, a small speaker, and accelerometer and gyroscope sensors for gesture operations. The battery is

a lithium-ion package that you have to keep charged like the phone itself.

So, what does this watch do? First, it relays messages from your phone including calls, texts, email, or whatever and lets you decide what further action to take. With its internal microphones and speaker, you can receive and make calls directly from the watch. The Galaxy Gear also has voice recognition and response, so you can check the weather or activate one of the many apps. The watch is programmable and so is customizable.

## THE PEBBLE WATCH

While the Galaxy Gear watch is tied to the Note, the Pebble can be used with most Apple or Android smartphones. It connects by Bluetooth, so all you need to do is download the Pebble app to your phone. The Pebble has a 1.26 inch e-paper mono screen with LED backlight. It is not a touch screen but uses several buttons on the side of the watch to activate the various

■ **FIGURE 4.** The Sony SmartWatch 2 features a color screen and easy access to social media.



functions. The Pebble has an 80 MHz ARM processor, RAM, and the Pebble OS. Sensors include an accelerometer, a compass, and an ambient light sensor. The battery is lithium-ion with USB charging cable.

As for functions, the Pebble lets you receive phone call notifications. You cannot answer or make a call from the watch. However, you can receive text messages and receive email notifications. The watch tells time and offers you eight different watch "faces." It also serves as a music controller to select and play songs on your phone. This Pebble model is the first of what is expected to be several models, some with a more sophisticated repertoire.

## SONY SMARTWATCH 2

Sony was one of the first to offer a smartwatch extension to a smartphone. This new model is better than the first (**Figure 4**). Like all the others, it communicates with Android smartphones (like Sony's own Xperia models) via Bluetooth. It does not accommodate the iPhone now, but future models are expected to. You download apps to your phone for the functions you wish to enable. The

## Feedback Motion Control

### The Old Way

- 1) Build robot
- 2) Guess PID coefficients
- 3) Test
  - 3a) Express disappointment
  - 3b) Search Internet, modify PID values
  - 3c) Read book, modify PID coefficients again
  - 3d) Decide performance is good enough
  - 3e) Realize it isn't
- 3f) See if anyone just sells a giant servo
- 3g) Express disappointment
- 3h) Re-guess PID coefficients
- 3i) Switch processor
- 3j) Dust off old Differential Equations book
- 3k) Remember why the book was so dusty
- 3l) Calculate new, wildly different PID coefficients
- 3m) Invent new, wildly different swear words
- 3n) Research fuzzy logic
- 3o) Now it is certainly not working in uncertain ways
- 3p) Pull hair
- 3q) Switch controller
- 3r) Reguess PID coefficients
- 3s) Switch programming language
- 3t) Start a new project that doesn't need feedback control
- 3u) See parts in box. Feel guilty. Go back to old project
- 3v) Start testing every possible combination of PID coefficients
- 3w) Apply eye drops to red, blurry, sleep-deprived eyes
- 3x) Well, it's working!
- 3y) Decide not to do any more projects that require control systems
- 3z) Wonder why someone doesn't just make a thing that tunes itself

### The Kangaroo x2 Way

- 1) Build robot
- 2) Press Autotune
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watch has a 1.6 inch LCD screen, gives programmed alarms, and provides a vibration when a call, text, or email comes through. You can also access Facebook and Twitter with it. Like the others, the SmartWatch 2 uses a micro-USB cable for recharging.

## QUALCOMM TOQ

The Qualcomm Toq is similar to other smartwatches in function, however, it only works with Android phones at this time. It uses Qualcomm's unique color Mirasol touch screen, and it is always on. One variation is optional Bluetooth dual headsets for stereo music playing. It uses a wireless charger rather than a charging cable. The Toq is not yet available, but should be competitive with other smartwatches once it is.

## HOT WATCH

The HOT watch – or Hands On Talk – is a product of PH Technical Labs. It works with both Androids and iPhones; connection is by Bluetooth. With its internal microphone and speaker, it lets you make and receive calls by just holding the watch to your face. The HOT watch is not yet available, but is on the way and offers competitive features.

## A WORK IN PROGRESS

The smartwatch movement is in its infancy right now. Currently, you can buy the Sony, Pebble, and Samsung models if you want to be an early adopter. Otherwise, wait for some of the other models to debut. Even Apple is said to be working on an iWatch, so keep an eye out for it in the coming months.

With prices in the \$150 to \$300 range, I predict these gadgets will be a success. That famous Dick Tracy TV watch is almost here. I may even get one (or two!) for myself. **NV**



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**\$2.55**  
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36Vdc, but operates smoothly and efficiently from 6-36Vdc. Built-in encoder with 3-wire termination. Steel 45mm (1.77") worm-gear attached to shaft with two set screws. No-load rating: 6800 RPM @ 12Vdc/ 250mA. 36.5mm diameter x 74mm (1.41" x 2.92") including encoder. 8" leads.

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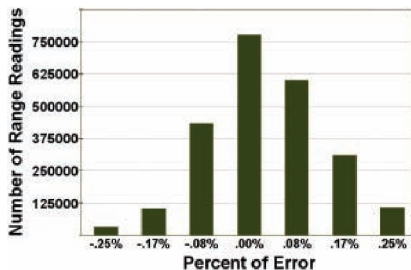
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CAT# HS-4900



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Histogram Report taken September 11, 2013 to September 16, 2013:

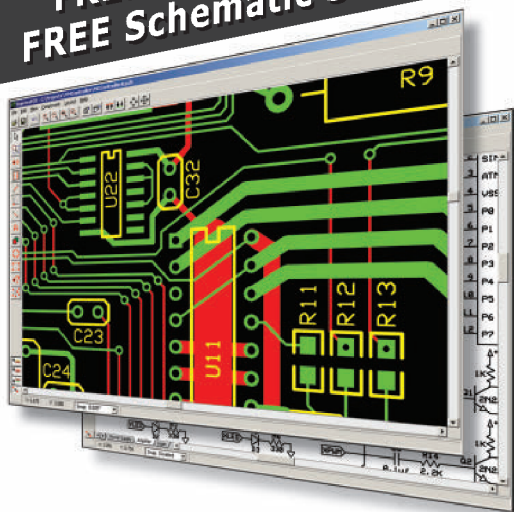
Reporting accuracy  $\pm$  the distance from the actual target:  
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# FEEDBACK

Continued from page 7

one could be added for tube matching. Reduced cathode electron emission is a common cause of failure in tubes — especially power tubes. If there isn't enough plate current, the output power drops.

The ideal way to keep your tubes matched would be to have both types of testers, then test the tubes (or new tubes) and record the numbers. Then, later the tubes could be re-tested to determine if they are getting weak. Mr. Asselin's suggestion to check for bad or unbalanced components is important for vintage amplifiers — especially for changed values of carbon resistors and leaky capacitors. I like his suggestion to use a dual-trace scope to compare the input waveform to the output waveform. I had never thought of this but I am going to try it.

Another method of tube matching is to use an adapter which goes to one of the output tubes and measures the current, such as the Bias King and Bias King Pro, the Alessandro Bias Meter, and the Bias Probe from JI ID Audio. If the unit has two adapters (like the Bias King Pro), use only one of them.

You need a good amplifier which uses the same tube type you are matching. Place the adapter in one of the output tube sockets of the amplifier, plug the tubes to be matched into that adapter one at a time, and record the current reading for each tube. This is measuring them in an amplifier circuit, and each tube is measured under the same conditions.

Several years ago, I decided that these adapters were rather high priced, so I built one for much less. It measures both the cathode current and the grid bias voltage of the tubes (grid to cathode or grid to chassis), using a digital panel meter for both bias and current measurements. I am planning to add a measurement of plate to cathode voltage, and a switching circuit with four or six tube adapters, so all of the tubes in a set can be measured without changing tubes in the adapters.

One thing I learned back in the tube days is avoid cheap tubes. Buy only name-brand tubes from a reputable supplier (counterfeits are always possible). Back then, there were a couple of suppliers of cheap tubes, with their own name on the tubes. I never knew the source of their tubes (they were not manufacturers), but I suspected they sold either used tubes or factory rejects. The suppliers I use most are Parts Express and Antique Electronic Supply ([www.tubesandmore.com](http://www.tubesandmore.com)). If you need tubes quickly, most music stores that sell guitar amps will have tubes in stock — often at fairly good prices.

Bill Stiles; Hillsboro, MO

Thanks Bill. Lots of pearls to consider.  
Bryan Bergeron

## GO FIGURE!

In the October Q&A, Figure 6 under the Tesla Coil Project is missing. Under the LTspice Tutorial sidebar, Figure 6 seems to be mislabeled.

Figure 7 and Figure 6 as presented do not appear to have supporting text. Thanks for the tutorial.

Peter A. Goodwin; Rockport, MA

I see the problem. I had two Figure 6s, so the numbering is screwed up. The one for page 21 is in **Figure A**. I don't know if I sent it originally because I failed to save the sent file. In the text on page 23, Figure 6 in the LTspice tutorial should be Figure 7 to go with the figure on page 24. Figure 6 on page 23 should have been Figure 8 and the text where it says "see Figure 7" should have said "see Figure 8." The INA128 diagram is shown here in **Figure B**. I apologize for the errors.

The files for these graphics are available at the October Q&A article link

Russ Kincaid

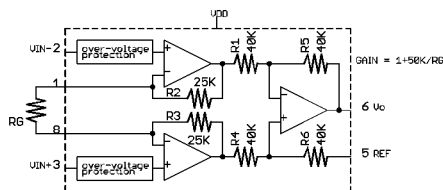


Figure A.

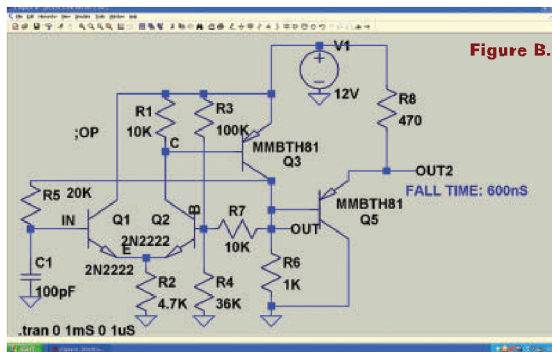


Figure B.

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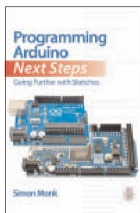
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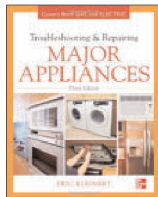
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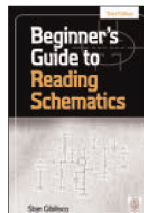
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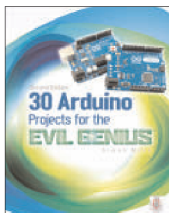
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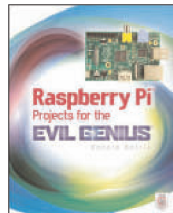
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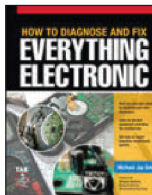


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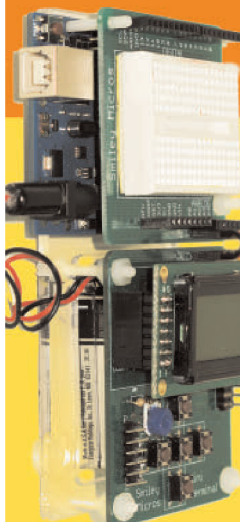
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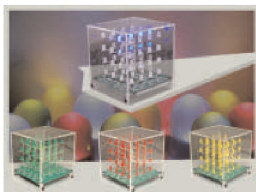
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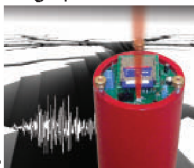
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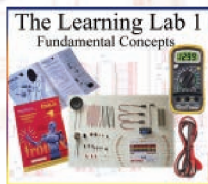
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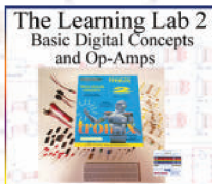
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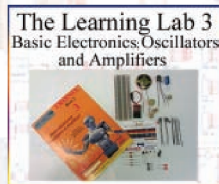
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## >>> ANSWERS

**[#10137 - October 2013]**

### Where Does a Kid Start?

*My 10 year old wants to start building circuits. What's a good resource for easy, safe, one hour projects for the younger set?*

**#1** The best place for your 10 year old to start in electronics is your local RadioShack. Check out this page from their website: [www.radioshack.com/family/index.jsp?categoryId=4446519&allCount=150&fbc=1&f=PAD%2FProduct+Type%2FLearning+kits&fbn=Type%2FLearning+kits&filterName=Type%2FLearning+kits](http://www.radioshack.com/family/index.jsp?categoryId=4446519&allCount=150&fbc=1&f=PAD%2FProduct+Type%2FLearning+kits&fbn=Type%2FLearning+kits&filterName=Type%2FLearning+kits)

I suggest starting with one of the smaller "x-in-one" lab kits (i.e., the "Elenco" one). If your kid is really bright, the Model 28-280 Electronics Learning Lab might be a good place to start. Once s/he starts to understand things more (say, in a few years), visit kit sites like Ramsey Electronics ([www.ramseyelectronics.com](http://www.ramseyelectronics.com)) and Velleman ([www.vellemanusa.com/home/?country=us&lang=enu](http://www.vellemanusa.com/home/?country=us&lang=enu)), or even review the RadioShack link above for "starter" kits to assemble. If you have a Fry's Electronics store in your area, they carry Ramsey and Velleman kits.

FWIW, I started my "electronics career" when I was in junior high (1975) with the RadioShack "100-in-one" Electronic Lab kit. It wasn't long before I was building more complex solder kits. Even today (at 53), the skills I learned from that RadioShack trainer are still in use on my job. If your

child displays an aptitude for electronics, see if your local junior and/or high schools have electronics curricula and definitely check out your local community colleges or trade school for two year Associate Electronics Technician programs (where I got my electronics career started all those many years ago).

**Ken Simmons**  
Auburn, WA

**#2** Check out your local RadioShack and search out some of their publications written by Forrest Mims III. His projects are straightforward and simple, and Forrest has a lot of years of teaching electronics and writing educational articles for electronics hobbyist magazines. Most of the parts he uses in his circuits are available at RadioShack.

**Dean Huster**  
via email

**[#10139 - October 2013]**

### Convert USB Webcam into Analog Video Source

*Used USB webcams are a dollar a dozen these days — much cheaper than native analog-out cameras (i.e., "security" cams). Is it possible or feasible to convert the USB cams to analog output? I presume it depends on the video chip used in the webcam — whether it has USB integrated or if that's a function of the small PCB on which it's attached. Any pointers, tips, advice, etc., would be greatly appreciated.*

Unless the webcam's PCB has an explicitly labeled location called video

or similar on the PCB, you'll have to use an oscilloscope to locate the raw video feed to the USB encoder chip. If there doesn't appear to be a raw video signal anywhere on the PCB, then you're out of luck.

Otherwise, once you locate that raw video point, simply get a length of shielded cable (the thinner the better) terminated with an RCA jack and (carefully) solder the center conductor to the raw video point on the PCB and the shield to a power ground location on the PCB. Insulate the shield to prevent unwanted shorts and keep it as short as possible.

Carve a notch in the webcam's body to feed the cable through, close up the webcam, and plug it into an active USB port. You should now be able to connect a shielded cable to the new RCA jack and run it to the YEL-LOW JACK of your video monitor and see what the camera is picking up.

**Ken Simmons**  
Auburn, WA

**[#101310 - October 2013]**

### Analog vs. Digital Meter

*I have an old Triplet analog multimeter and a new, no-name digital multimeter. A friend told me that, even though I can read out voltage to the second decimal place, my old Triplet is more accurate. I'm confused about the accuracy/precision difference. Can you clarify?*

Your question reflects common confusion between the interrelated terms **accuracy**, **resolution**, **linearity**, and **offset** with respect to measuring

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instruments. **Application** ought to also be considered.

Your Triplett uses a moving coil instrument having a pointer attached to the coil and a set of printed scales behind the pointer. The position of the pointer has a direct, analogous relationship to the amount of current flowing through the meter movement, hence the name "analog" in describing the instrument. The value of the current, voltage, or resistance being measured is interpolated from the appropriate printed scale at the point directly under the pointer position.

The digital voltmeter samples the applied voltage and produces a digital reading proportional to that voltage; the digital value presented is derived from a binary counter/register. Conversion from the analog measurement to digital presentation is commonly effected by feeding the digital readout value back through a digital-to-analog converter and comparing the converter voltage output to the (scaled) voltage of the original sample; the readout count is advanced until the comparison is "equal" (see next), at which point the digital readout indicates — as best as possible — the voltage being measured. In this implementation, the internal system counts in binary and the least significant counter bit is not displayed, whence the displayed value cannot be closer to the true value than  $\pm 1/2$  the value of the least significant digit in the display.

Both systems are affected by accuracy and linearity. The **accuracy** of the instrument expresses the limitation on its ability to indicate the true value of that which is being measured. "Accuracy" is expressed as a fractional deviation from unity: For a voltmeter, for example, its accuracy is equal to  $[1 - (\text{Vindicated}/\text{Vmeasured})]$  — thus, if a DC voltage is truly 100 volts but the instrument indicates 101 volts (or 99 volts), then the instrument is inaccurate by a factor of  $\pm 1/100$  and

its accuracy is said to be  $\pm 1\%$ . Accuracy is affected by environmental conditions, as well as inherent inaccuracies in its component parts (e.g., internal voltage dividers, etc.).

The **linearity** of the instrument expresses its ability to maintain its stated accuracy at any measurement value. Digital-to-analog converters have linearity issues and contribute this problem in digital measuring instruments. Analog instruments depend upon a linear relationship between pointer position and the restoring torque of the coil-position return spring.

Accuracy specifications commonly include the worst effects of linearity in the instrument for a measurement of any value within the specified measurement range, and within the stated environmental conditions.

**Resolution** is all too often confused with accuracy. Resolution relates to the ability of the observer to identify the measurement value being presented by the instrument. In an analog instrument, the resolution is the smallest value printed on the instrument scale (the least significant "tick" on the scale). If your Triplett is like mine (a model 630PL), it has a voltage measurement scale for the 0-10/0-50/0-250 volt ranges, and there are 10 "ticks" between each numeric value: The resolution of the instrument depends, therefore, upon the voltage range in use, and is 0.2 volts on the 10 volt scale, one volt on the 50 volt scale, and five volts on the 250 volt scale. Stated another way, as there are a total of 50 ticks on the 10/50/250 volt scale, the instrument resolution is  $1/50$ th (or 2%) of full scale, and this is generally the way in which resolution is expressed for an analog instrument.

In a digital instrument, the resolution is equal to the number of digit positions being displayed, and *herein lies the confusion between resolution and accuracy*. Let us consider a four-

digit display (= its resolution), having an accuracy of  $\pm 1\%$ . If a DC voltage of 50 volts (true value) is measured, the display might read "50.37." For  $\pm 1\%$  accuracy, the instrument reading must be within the interval 49.5 to 50.5 volts. The best that we can expect is three digits' accuracy, and thus a reading of "50.37" creates an expectation of 0.1% accuracy, when in reality we should interpret the reading as 50.4 volts — that is, the displayed value rounded to three digits. **Resolution and accuracy are independent qualities.**

This brings up the matter of **application**: Digital instruments use a continuous sequence of sampling and measurement to produce their readings. Digital instruments are best used for steady-state conditions — e.g., a voltmeter on a bench power supply — else they will attempt to read changing values and produce a blur of digits that is frequently impossible to read. I'm partial to analog instruments because I rarely need extreme resolution but I like the inherent ability of the analog instrument to average over variations in the measurement value.

For example, my old Prius has passed its warranty date and I'd like to tinker with the electrical system — at least to the point of inserting a zero-center ammeter measuring shunt into the high voltage bus at the battery terminal. The current demand on the propulsion battery is rarely constant and can shift in value and even polarity from moment to moment. A moving coil instrument is perfect for this, as it will give me an indication of magnitude and direction of current flow on a continuous basis. This would never be possible using a digital instrument.

Finally, the matter of **offset**: Offset is a constant value difference between true value and indicated value. It is most important that your Triplett instrument be zeroed. With the pointer at rest and the selector switch in the OFF position, and with the instrument



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oriented in the position commonly used (either standing up or lying down), use the setscrew over the coil pivot point to adjust the pointer so that it lies directly over the "0" mark on the scale. When the instrument is used for resistance measurement, use the Ohms Adjust control with the test leads shorted together to ensure that the pointer lies over the 0 ohms mark on the scale.

Offsets are much less likely to occur in digital instruments because suitable compensations can be built into the design. The one exception that I can think of would be

associated with high input impedance instruments (solid-state or vacuum tube voltmeters, for example) in which electrochemical differences between measurement probes and the surfaces being probed might cause slight offset voltages for which internal compensation would not apply.

I hope the above discussion answers your question. One of my frequent gripes is the marketing of the term "accurate." In my local hardware store, there is a shelf containing outdoor thermometers. The advertising blurbs on the packages all state that the instrument has "guaranteed accuracy."

"Accuracy" without a stated value is a meaningless term. It's easy to guarantee a meaningless statement. And, of course, for the digital varieties of these instruments, the manufacturer is quite content to let the buyer equate resolution with accuracy. (The best way to buy a thermometer at the hardware store is to examine all of the specimens on the shelf of the model desired, and choose the one that best represents the group consensus, excluding those having markedly different readings.)

**Peter A. Goodwin**  
Rockport, MA

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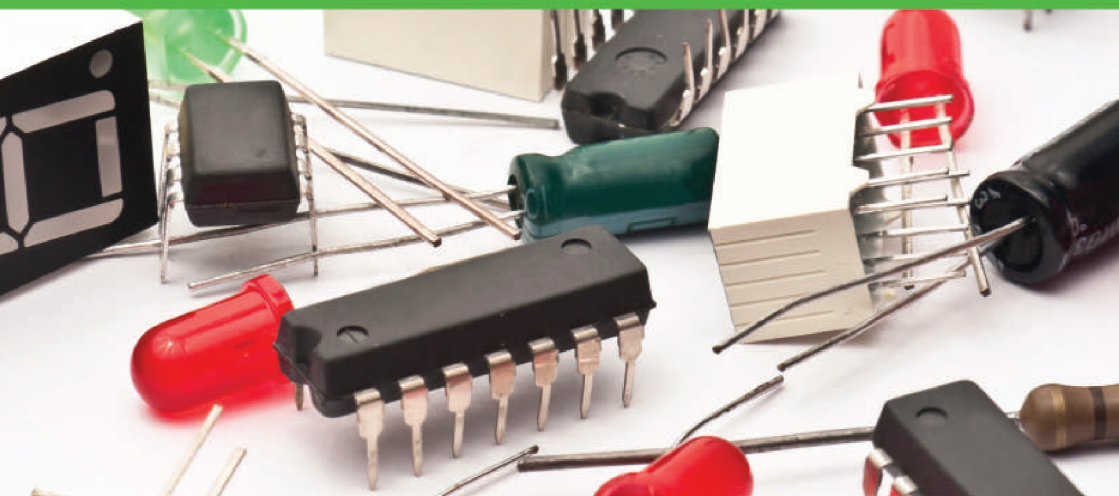
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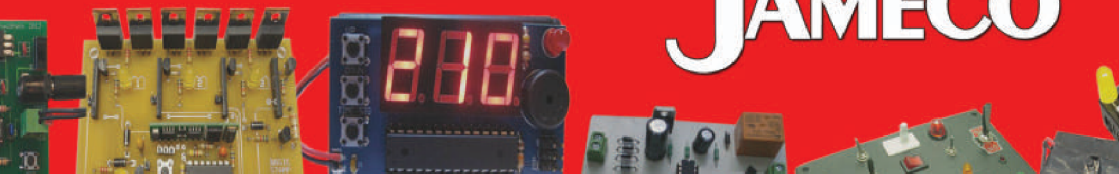


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MK117 LED Christmas Tree Kit \$24.95

### LED Animated Holiday Bell

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MK122 LED Animated Bell Kit \$18.95

### 3D LED Christmas Tree

Not your average LED display! 4 branch sections give this tree a true 3D look! 16 red LEDs light it up with yellow LEDs for you to customize your tree! The base of the tree is actually the 9V battery acting as a self supporting base! Now that's pretty neat!

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MK172 Sound Activated LED Star Kit \$19.95

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MK169 LED Flashing Holiday Star \$12.95

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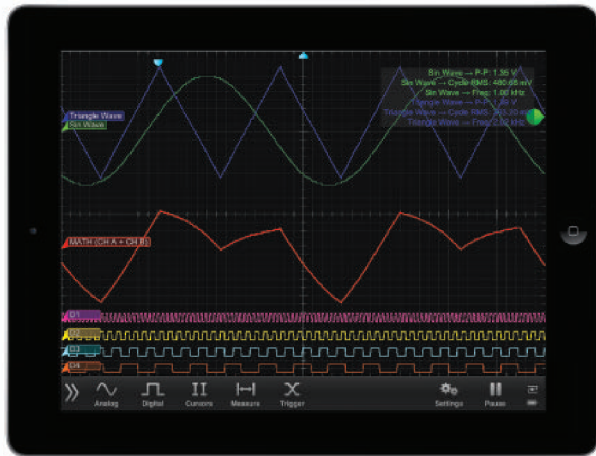
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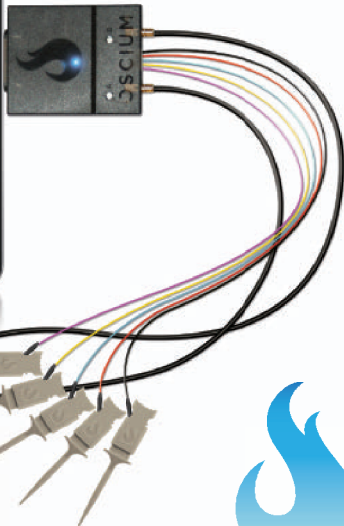
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